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In-Plant Control of Pollution

Upgrading Textile Operations to Reduce Pollution

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The first volume of this series consists of two sections; the first section deals with water pollution abatement while the second handles air pollution aspects arising from dyeing and finishing operations. In the second volume, it is explained that the textile industry is constantly changing manufacturing processes and resulting wastewater. To meet this change, new wastewater treatment systems are designed and explained to handle this wastewater.

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Upgrading Textile Operations
to Reduce Pollution

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This publication was coordinated by the Institute of Textile Technology, Charlottesville, Va., with the help of numerous people in the textile industry as noted in each chapter or section.

NOTICE

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INTRODUCTION*

The total process-water consumption of the textile industry in 1972 was about 125 billion gallons per year. About 680 wet-process plants of the more than 7,000 plants in the United States account for 95 percent of the water used. Only about 20 percent of the water was discharged untreated; the remainder underwent municipal or onsite secondary waste treatment. The textile industry recognizes the necessity for close cooperation with the EPA if the national goals of water-pollution abatement are to be realized. The need for upgrading existing wastewater treatment and procedures to conform or to meet EPA guidelines and standards of performance applicable to the textile industry may arise from one or more of the following reasons:

- Lack of proper plant operation and control
- Inadequate plant design
- Changes in wastewater flow or characteristics
- Changes in treatment requirements

There are many areas relating to air pollution that concern industries, including the textile industry, but in this publication, the concern is confined to air pollution that arises from dyeing and finishing operations. The Clean Air Act of 1963 and subsequent amendments, particularly those of 1970, relate to the protection and enhancement of air quality in the United States. Both authorize and mandate the implementation of Federal programs and programs for State-Federal cooperation designed to attain these objectives within strict time schedules.

The first part of this publication is concerned with water, and the second part is concerned with air. The various areas under Water Pollution Abatement to be given consideration are (a) The Waste Survey, (b) Major Sources of Waste, (c) Flow Reduction, (d) Water Reuse, (e) Waste Segregation, (f) a panel discussion on Substitution of Processes and Materials, and (g) Pretreatment of Textile Wastes, whereas the areas to be included under Air Pollution Abatement, within the previously given limitations imposed, are (a) the Emissions Survey, (b) Particulate Control, and (c) Solvent Recovery.

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*Prepared by Jack Compton of the Institute of Textile Technology, Charlottesville, Va.

Part I
WATER-POLLUTION ABATEMENT

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Chapter I

THE WASTE SURVEY*

INTRODUCTION

One of the first major steps in an industrial water pollution control program is to define the scope of the abatement effort by determining the characteristics of the wastewater. This chapter deals with the wastewater characterization or wastewater-survey segment of the pollution-control program and also with a continuing survey to monitor changing characteristics and to aid in evaluating production changes.

The waste-survey topic can be broken into the following four essentially chronological segments:

- Preliminary survey
- Detailed survey
- Data evaluation
- Continuing monitoring

PRELIMINARY SURVEY

The initial effort in a water-pollution-control program is typically a feasibility study that attempts to answer the following questions:

- What will be the discharge criteria?
- What are the likely methods of treatment?
- What in-plant alternates are available for waste reduction?

The data base for this feasibility study is the information gathered from a preliminary waste survey. The goals of this initial survey are to

- Determine the approximate volume of wastewater
- Determine the approximate wastewater characteristics
- Define the major waste sources and possible methods of in-plant waste reduction and control
- Define the approximate characteristics of the raw-water source and the receiving stream

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*Prepared by T. L. Rinker of Blue Ridge-Winkler Textiles, Bangor, Pa.

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The purpose of the survey, therefore, is not to define the problem for the purposes of final commitments, but only to obtain an accurate overview that will allow selection of the most likely problem solutions from the many that are available. The duration and complexity of this work will vary proportionally with the size and complexity of the mill and with the degree to which experience or the literature can provide direction or answers.

Any preliminary survey should consist of the following segments:

- Development of an approximate water and wastewater balance
- Wastewater sampling and analysis
- Review of manufacturing operations and raw material usage
- Flow measurement, sampling, and analysis of major waste sources
- Sampling and analysis of the raw water and receiving stream

Incoming-water information for the mill can be developed from any of the methods shown in table I-1. Ideally, there will be water meters installed on the major branches of the mill-distribution system, but this is seldom the case, and an approximate breakdown of the water flow is usually necessary. These water data should cover several 1-month periods in order to reflect various production levels and product mixes. This water use should be broken down on a daily basis, and the production level for each area recorded. The final result of this work will be a drawing such as that shown in figure I-1, which indicates the distribution system, the water usage in gallons per day, and the water usage rate in gallons per pound of cloth.

Similarly, a detailed map should be developed showing the location of major sewer lines and sources of wastewater. Process, sanitary, and storm water sources should be indicated, as should be points of discharge.

Typically, most mills do not have an accurate drawing showing the locations of all sewer lines and waste sources, but it is important that this map be developed. Dye tracing should be used to identify what happens to all known sources and to check for cross-connections between separate sewer systems.

Table I-1.—*Methods of flow measurement for incoming water and wastewater*

Water	Method
Incoming	Daily water-meter readings Monthly water bills Records of pump running time Estimation of capacity of water-use points
Waste	Discharge through an orifice Discharge over a weir Discharge through a flume Salt injection Dye or float timing Timing of a container Pump timing Current meters Venturi, orifice, or magnetic flow meters Rotameter

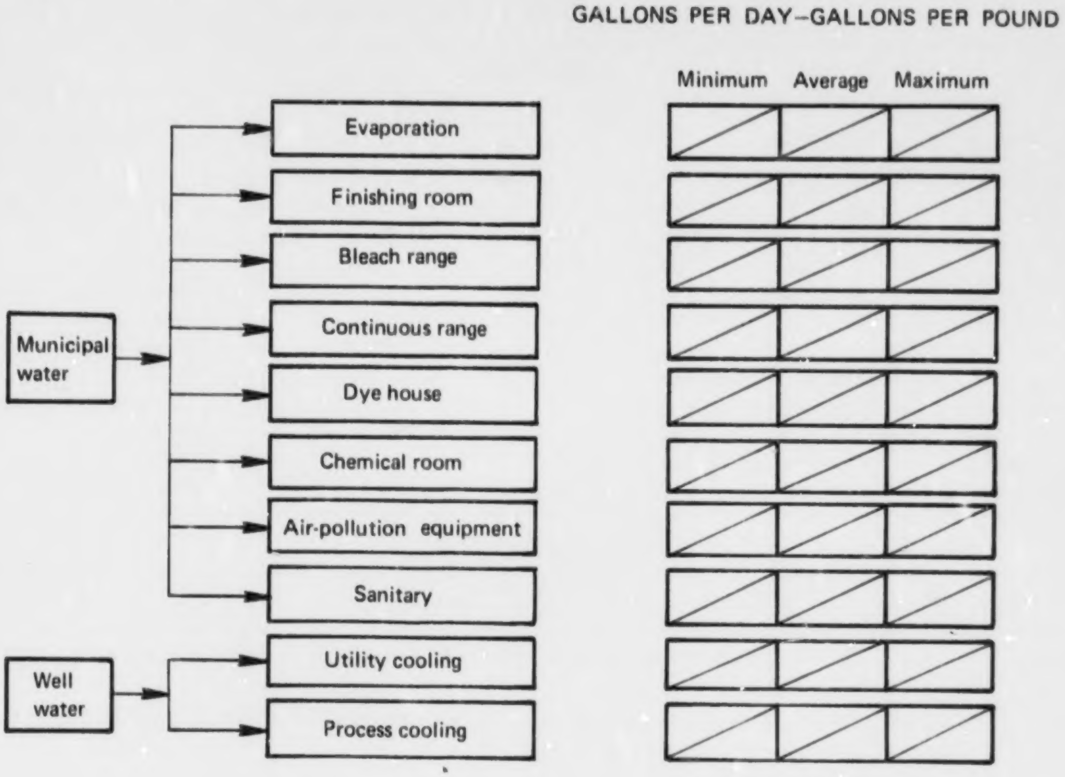

GALLONS PER DAY–GALLONS PER POUND
Minimum
Average
Maximum
Municipal water
Well water
Evaporation
Finishing room
Bleach range
Continuous range
Dye house
Chemical room
Air-pollution equipment
Sanitary
Utility cooling
Process cooling

Figure I-1. Water-distribution system for a finishing plant.

Flow rates for sanitary and storm water sources can be estimated, but flow rates for the process sewer or sewers should be determined by flow measurement. The method of flow measurement used is dependent on the volume of water, the physical restraints of the measurement point, and the accuracy required. Tables I-1 and I-2 and figure I-2 show the various methods of measurement normally used and the conditions under which they are appropriate.

For a preliminary study, flows should be measured once per hour over a 24-hour period 1 day per week for 4 weeks. These data can then be compared with production and water-use data to extrapolate to various production levels.

The final result of this work will be a drawing such as that shown in figure I-3, which indicates the sewer system, the flow in gallons per day from the major waste sources, and the flow rate in gallons per pound of cloth from the major waste sources.

Simultaneous with the flow measurement, sampling of the wastewater should be accomplished. An automatic sampler station that will provide hourly samples is recommended. This equipment should allow for either continuous or intermittent sampling so that each hour sample will be a composite. Figure I-4 shows various sampling equipment arrangements.

The test methods recommended by the EPA in the June 29, 1973, Federal Register are summarized in table I-3.

Table I-2.–*Comparison of flow-measurement techniques*

Specific notes

Method	Flow range	Cost	Ease of installation	Accuracy	Application
Orifice	Small	Medium	Fair	Excellent	Pipe and open channel
Weir	Small to large	Medium	Fair to difficult	Good to excellent	Open channel
Flume	Small to large	High	Difficult	Excellent	Open channel
Salt injection	Small to medium	Low	Fair	Good	Pipe and open channel
Dye or float	Small	Low	N/A	Fair	Open channel
Container	Small	Low	N/A	Good	Pipe and open channel
Pump	Small to large	N/A	N/A	Fair	Pipe
Current meters	Small to large	Medium	Fair	Fair	Pipe and open channel
Flow meters	Small to large	High	Difficult	Excellent	Pipe
Rotameter	Small to medium	Medium	Fair	Good	Pipe
Open end pipe	Small to medium	Low	Fair	Fair	Open channel

General notes

Method	Note
Orifice	An orifice can be used to determine the flow from a vessel through a circular outlet by measuring the height of water in the vessel.
Weir	A weir is used to determine flow by measuring the difference in elevation between the discharge edge (crest) and the upstream water level. Weirs are simple, reliable measurement devices when they are installed correctly. Accuracy is ±5 percent. ● The weir crest must be sharp ● Air must have access to the underside of the falling water ● Leaks must be sealed ● Weir must be exactly level ● Weir approach must be kept clean of sediment ● The head should be measured back of the crest at least five times the height ● The upstream channel should be reasonably free from disturbances ● A weir measurement should consist of the average of several equally timed readings There is more head generated on a V-notch weir; therefore, these weirs are used for smaller flows in order to maintain accuracy. Automated level recorders (pressure or mechanical) should be used for permanent installations or deep sewers. A Parshall flume is a permanent installation that measures the difference in water levels caused by a constriction in the channel cross section. The advantages of dependable accuracy, low head loss, and large capacity range are offset by the high installation costs. The flumes can be purchased as a complete package with flow recording equipment. An accuracy of ±5 percent is obtained when the equipment is installed properly. ● Standard dimensions must be used ● The downstream head should not exceed the recommended percentage of upstream head ● The upstream head is measured in a stilling well ● The flume is installed in a straight channel, and there is no close upstream turbulence

Table I-2.–*Comparison of flow-measurement techniques.–Concluded*

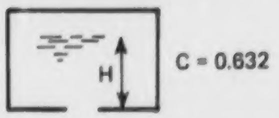
General notes

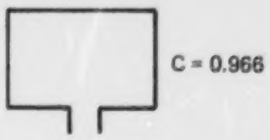
Method	Note
Salt injection	The salt injection method depends on determining the downstream concentration of a readily detectable chemical (e.g., lithium chloride) when a known quantity of the material is injected upstream. The method is useful when ● The physical location of the sewer (e.g., depth) makes weir measurement impossible ● Waste is flowing under pressure ● When accurate total flow values are required, and mechanical or frequent manual weir height measurement is not feasible ● When a simultaneous sampling program is being conducted
Floats	This method requires the measurement of water depths and velocity and should only be used for approximations of flow.
Container	This method requires measuring the time for a discharge to fill a vessel of known volume and is good only for small flows.
Pump	This method requires timing the amount of time a pumping is running and determining the water volume from the pump characteristics. It should only be used for approximations of flow.
Current meters	This method requires determining the cross sectional area of a channel and measuring the water velocity in several segments. The method is used for measuring small stream flows.
Flow meters	Flow meters measure water flow in pressure systems by detecting differential pressure across a contraction (e.g., Venturi tube or orifice plate) or by detecting the electrical potential produced by the flow. This equipment is accurate and reliable over a wide range of flows but is an expensive, permanent installation.
Rotameters	These meters measure water flow by the water turning a set of gears to totalize flow or by suspending a float to indicate instantaneous float. The equipment will vary widely in cost depending on size and accuracy requirements.
Open-end pipe	This method requires the measurement of vertical fall of a free-flowing discharge from a pipe and should only be used when other methods are not practicable.

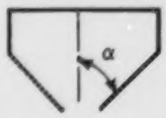
At the end of a 4-hour period, the hourly samples should be chemically preserved and refrigerated unless analyzed immediately. Table I-4 shows the preservation procedures recommended by the EPA. The EPA *Methods of Chemical Analysis of Water and Wastes* is recommended as the procedural standard. Figure I-5 shows the results of a flow and sampling survey.

The analytical schedule for the process sewer samples is dictated by the discharge criteria and by a knowledge of manufacturing chemicals. EPA and the States require the filing of a permit application for obtaining a discharge permit under the 1972 amendments. This application requires information on some 60 parameters. In order to limit the extent of the analysis program, it is recommended that the schedule shown in table I-5 be used for the preliminary survey.

The work discussed above is to develop the information necessary for final treatment of the wastes. Of equal importance is the in-plant analysis to define major sources and possible methods of waste reduction and/or segregation. This work is started by developing (1) a material balance for each major production unit and (2) a history of chemical and dyestuff usage.





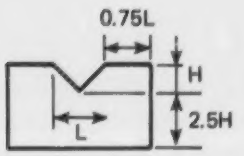


$$Q = cA\sqrt{2gH}$$

Q = discharge, ft^3/s
c = constant
A = orifice area, ft^2
V = velocity, ft/s
g = acceleration due to gravity, ft/s^2 = 32.2
H = head, ft

α =	67½°	45°	22½°
c =	0.684	0.753	0.882

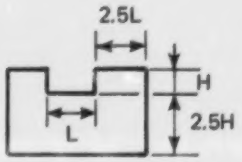
A. ORIFICE



90° V Notch

$$Q = 2.52H^{2.47}$$

Q = discharge, ft^3/s
H = head, ft



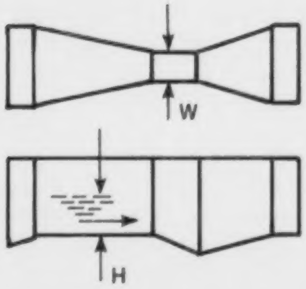
Rectangular Weir

$$Q = 3.33\ LH^{1.5}$$

Q = discharge, ft^3/s
H = head, ft
L = length of weir, ft

1. $H < 1/3\ L$
2. $0.5 < H < 2.0$
3. approach velocity less than 1 ft/s

B. WEIRS



$$Q = 4WH^n$$

C. PARSHALL FLUME

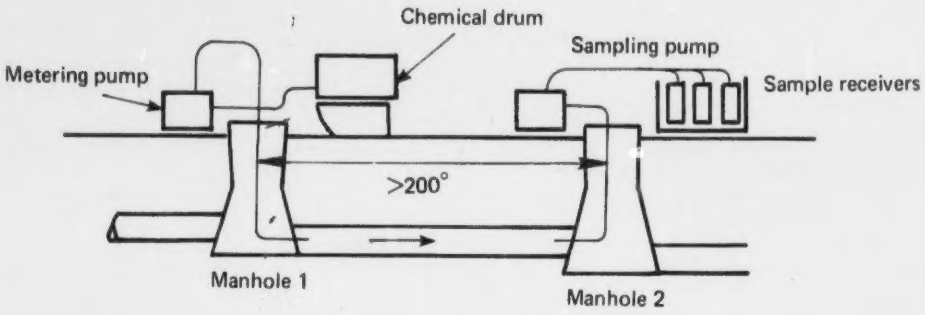
Q = discharge ft^3/s
W = throat width, ft
H = head, ft
n = $1.522W^{0.026}$

Figure I-2. Formulas for flow measurement by various devices.

$$Q = A'k\ (D/T)$$

Q = discharge, ft^3/s
A' = area and welted sewer, ft^2
D = distance between manholes, ft
T = average time, s
K = 0.8 for floats and 1.0 for dyes

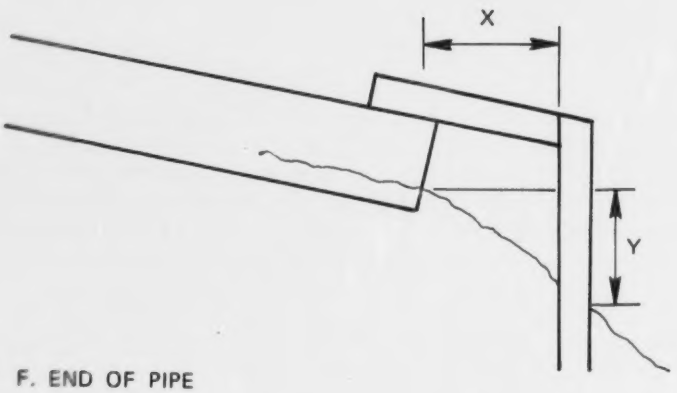
D. FLOATS


Chemical drum
Sampling pump
Metering pump
Sample receivers
>200°
Manhole 1
Manhole 2

$$Q = \frac{Q_t\ (C_t - C)}{C}$$

Q = discharge, ft^3/s
Q_t = discharge of traces
C = concentration of tracer in water after injection
C_t = concentration of tracer being injected

E. CHEMICAL TRACERS



$$Q = \frac{1800\ AX}{Y}$$

F. END OF PIPE

Q = discharge, gal/min
A = area, ft^2
Y = distance from water level in pipe to water level in stream at X, ft.

Figure I-2. Formulas for flow measurement by various devices.—*Concluded*

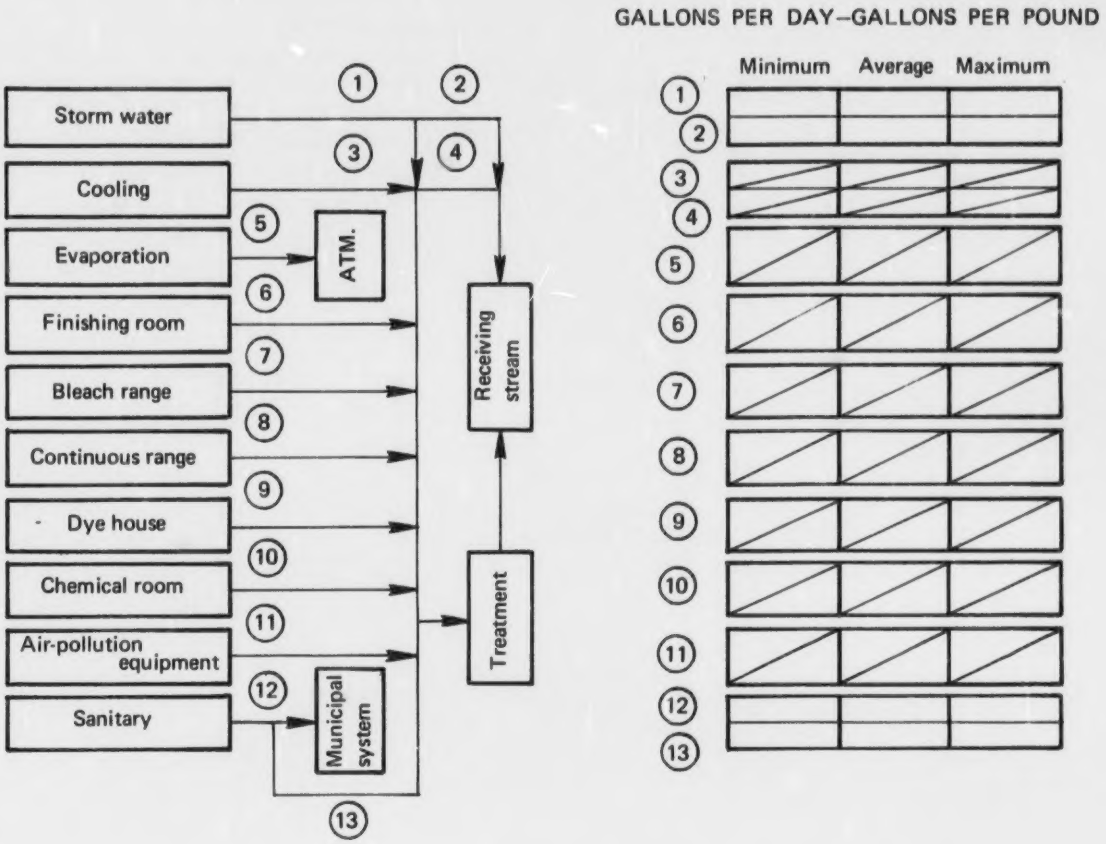

GALLONS PER DAY–GALLONS PER POUND
Minimum
Average
Maximum
Storm water
Cooling
Evaporation
Finishing room
Bleach range
Continuous range
Dye house
Chemical room
Air-pollution equipment
Sanitary
ATM.
Receiving stream
Treatment
Municipal system
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬

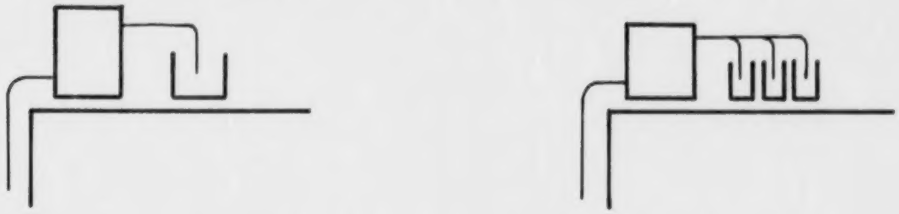
Figure I-3. Sewer-system schematic for waste survey.

The intent of the material balance is to indicate both the fabric and chemicals going into and out of a production unit. It is typical that the concentration of the chemicals coming from a production unit cannot be readily determined. Therefore, at least the wastewater characteristics should be indicated. The vendors of chemicals used in the mill can be of help in determining effluent concentrations of their materials. Examples of this work are shown in figures I-6 and I-7 and table I-6. The material balance analysis also serves as a check on process efficiency and may indicate potential cost-saving changes.

The intent of the analysis of chemical and dyestuff usage is to approximate the chemical nature of the wastewater. As in the case of the water balance, at this stage only one or two representative months need to be examined. The form of this analysis can be as that shown in table I-7 and will indicate the importance of various chemicals to the treatment system. As part of the in-plant sampling and analysis program, an analysis of the wastewater characteristics of the major chemicals at various concentrations may be made. The data, when combined with a knowledge of the concentration in the effluent, will help to evaluate the treatment alternatives.

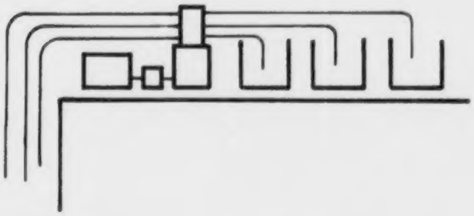
Types of Samples

- Grab: A single, manually collected sample
- Continuous: A single sample or a series of samples taken over a period of time by either
  - A continuous small volume of flow
  - An intermittent small volume of flow
  - An intermittent small "Cut" of a larger volume of flow
- Composited: A single sample made up of flow-proportional amounts of several individual samples. The sample may be either a grab or a continuous composite.

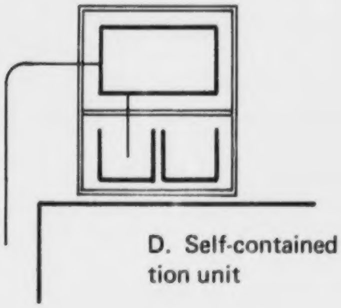


A. Portable, self-contained sampling unit, variable speed, on/off flow, single composite

B. Same as "A" but with hourly compositor

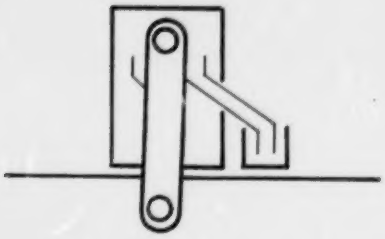


C. Multiple-head, variable-speed pump with on/off flow for semipermanent installation

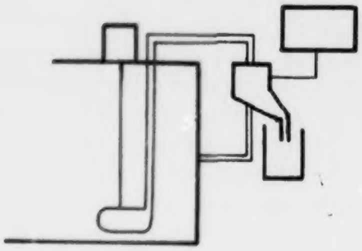


D. Self-contained sampling unit with refrigeration unit

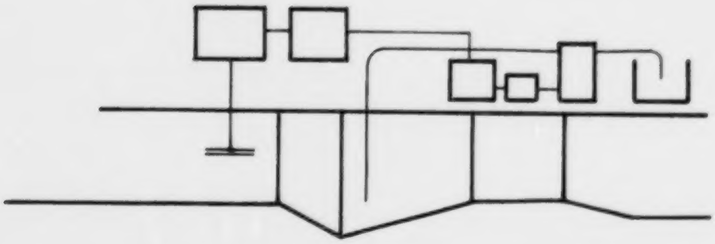
Figure I-4. Seven typical methods of sampling wastes.



E. Dipper sampler



F. Mechanical sampler with pump to obtain a "split" or "cut" sampler



G. Permanent flow and sample station consisting of a flow recorder, transmitter, variable-speed pump, and pump timer mounted over a Parshall Flume

General notes:

- The sample point should be at approximately one-third of the water depth for sewers and channels
- Sampling point should not be adjacent to turbulent area, but flow should be mixed to insure representative sampling, particularly of solids
- Tube size and sample velocity should be considered to insure proper handling of solids
- Flow variations can normally be adequately covered with a sampling frequency of 10-15 minutes unless the variations are very large
- For suction lifts of greater than 12 feet, submersible pumps should be used
- Sample containers should be glass or nalgene and adequately washed after being emptied
- For winter sampling, tubing should be placed in heat-traced pipes and sampler placed in a box with a heat lamp or heat pad

Figure I-4. Seven typical methods of sampling wastes.—*Concluded.*

Table I-3.—*Test methods recommended by the EPA*

Measurement	Reference[1]
Alkalinity	C, p. 6
Ammonia nitrogen	C, p. 134
Arsenic	A, p. 65, 4A (digestion) A, p. 62, method 104A (measurement)
Boron	A, p. 69
Cadmium	C, p. 83
Chloride	B, p. 21, method A
Chromium	C, p. 83
Conductance specific	B, p. 162, method B
Copper	C, p. 83
Fluoride	A, p. 171, method 121A with p. 174, method 121C
Hardness	A, p. 179, method 122A
Iron	C, p. 83
Magnesium	C, p. 83
Manganese	C, p. 83
Mercury	D
Nitrate nitrogen	A, p. 458, method 213B
Nitrogen, total Kjeldahl	A, p. 469, method 216
Organic carbon, total	C, p. 221
Organochlorine pesticides	D, Appendix A, Part II
Orthophosphate	C, p. 243
Oxygen demand, biochemical	A, p. 489, method 219
Oxygen demand, chemical	A, p. 495, method 220
Phosphorus, total	C, p. 242
Selenium	A, p. 296, method 150A
Silver	C, p. 83
Solids, total	A, p. 535, method 224A
Surfactants	A, p. 559, method 229
Suspended nonfilterable solids, total	A, p. 537, method 224C
Temperature	A, p. 559, method 162
Zinc	C, p. 83

[1] "A" refers to *Standard Methods for the Examination of Water and Wastewater,* 13th edition, 1971. This publication is available from the American Public Health Association, 1015 18th St., NW., Washington, D.C. 20036.

"B" refers to the *Annual Book of Standards,* Part 23, Water; Atmospheric Analysis, 1972. This publication is available from the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

"C" refers to *Methods for Chemical Analysis of Water and Wastes,* Environmental Protection Agency, Analytical Quality Control Laboratory, Cincinnati, Ohio. This publication is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock no. 5501-0067).

"D" refers to National Pollutant Discharge Elimination, appendix A, Federal Register, 38, No. 75, pt. II.

Table I-4.—*Sample preservation requirements for various parameters*

Parameter	Preservative	Maximum holding period
Acidity-alkalinity	Refrigeration at 4°C	24 hours
Biochemical oxygen demand (BOD)	Refrigeration at 4°C	6 hours
Calcium	None required	7 days
Chemical oxygen demand (COD)	2 ml H_2SO_4 per liter	7 days
Chloride	None required	7 days
Color	Refrigeration at 4°C	24 hours
Cyanide	NaOH to pH 10	24 hours
Dissolved oxygen	Determine on site	No holding
Fluoride	None required	7 days
Hardness	None required	7 days
Metals, total	5 ml HNO_3 per liter	6 months
Metals, dissolved	Filtrate: 3 ml 1:1 HNO_3 per liter	6 months
Nitrogen, ammonia	40 mg $HgCl_2$ per liter—4°C	7 days
Nitrogen, Kjeldahl	40 mg $HgCl_2$ per liter—4°C	Unstable
Nitrogen, nitrate-nitrite	40 mg $HgCl_2$ per liter—4°C	7 days
Oil and grease	2 ml H_2SO_4 per liter—4°C	24 hours
Organic carbon	2 ml H_2SO_4 per liter (pH 2)	7 days
pH	Determine on site	No holding
Phenolics	1.0 g $CuSO_4$/1 + H_3PO_4 to pH 4.0 - 4°C	24 hours
Solids	None available	7 days
Specific conductance	None required	7 days
Sulfate	Refrigeration at 4°C	7 days
Sulfide	2 ml Zn acetate per liter	7 days
Threshold odor	Refrigeration at 4°C	24 hours
Turbidity	None available	7 days

Source: *Methods for Chemical Analysis of Water and Wastes*, EPA, 1971.

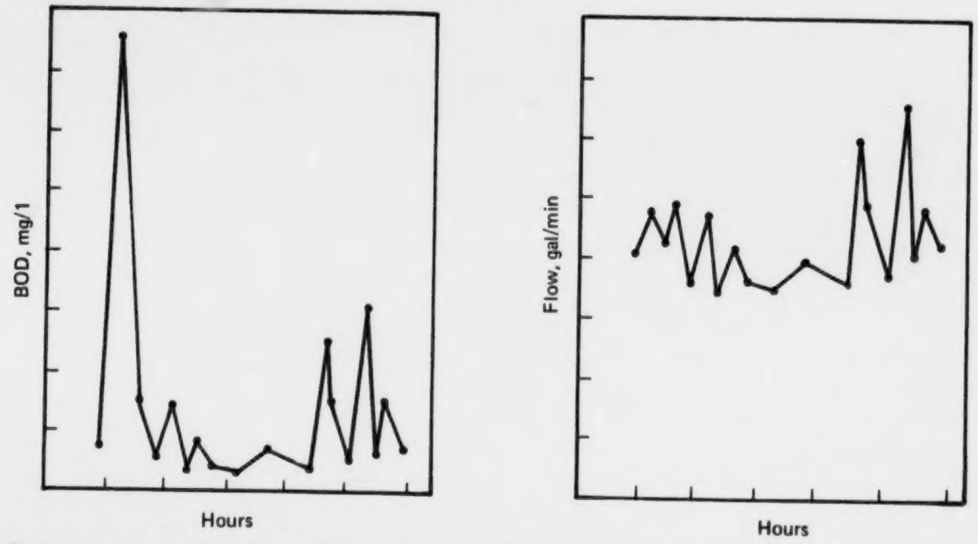


Figure I-5. Typical preliminary survey results of BOD and flow measurements as a function of time.

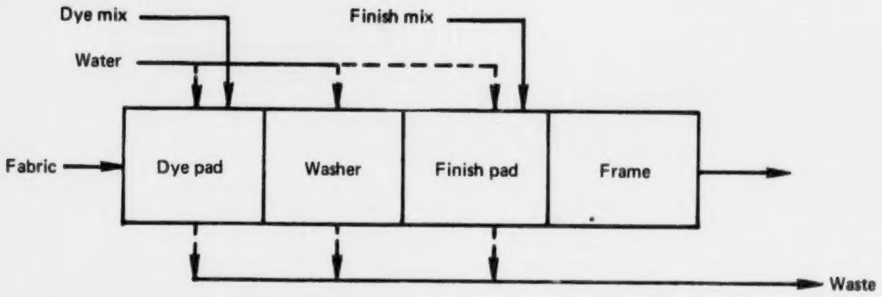
Table I-5.–*Preliminary survey analytical requirements on samples collected*

Time of measurement	Item measured
First set of samples	
Time-of-flow measurement	Dissolved oxygen
	Temperature
Hourly	BOD
	COD
	Suspended solids
	pH
	Color
	Alkalinity
24-hour composite	Dissolved solids
	Various forms of nitrogen
	Phosphorus
	Turbidity
	Various forms of sulfur
	Halogens
	Cyanide
	Phenol
	Surfactants
	Aluminum
	Arsenic
	Cadmium
	Calcium
	Chlorinated hydrocarbons
	Coliform bacteria
	Cobalt
	Chromium
	Copper
	Iron
	Lead
	Magnesium
	Manganese
	Mercury
	Nickel
	Potassium
	Zinc
Second, third, and fourth set of samples	
Instantaneous and hourly	Same as first set
24-hour composite	Dissolved solids
	Forms of nitrogen ($p>0.1$)
	Phosphorus
	Turbidity
	Forms of sulfur ($p>0.1$)
	Halogens found ($p>0.1$)
	Cyanide ($p>0.01$)
	Phenol
	Surfactants
	Aluminum ($p>1.0$)
	Arsenic ($p>0.01$)
	Cadmium ($p>0.01$)

Table I-5.—*Preliminary survey analytical requirements on samples collected.—Concluded*

Second, third, and fourth set of samples	
Time of measurement	**Item measured**
24-hour composite—*Continued*	Calcium ($p>10$) Cobalt ($p>0.01$) Chromium Copper Iron Chlorinated hydrocarbons ($p>0.01$) Coliform bacteria ($p>1000$) Lead ($p>0.01$) Magnesium ($p>10$) Manganese ($p>1$) Mercury ($p>0.001$) Nickel ($p>0.001$) Potassium ($p>10$) Zinc

Note.—The shorthand ($p>0.01$) indicates that further analysis is necessary only if the first analysis indicates a value greater than 0.01 mg/l.



	Dye pad	Washer	Finish pad	Equipment wash
pH				
BOD				
COD				
Color				
Flow				

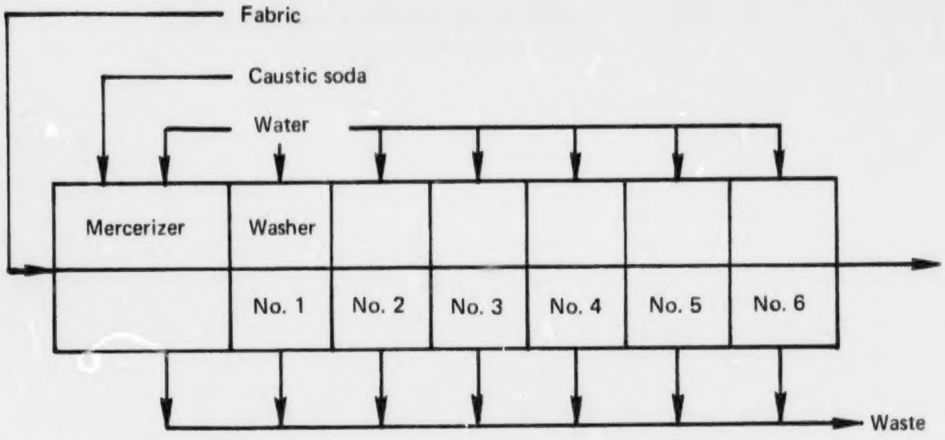
Dye formulas ____________ Finish formulas ____________ Products ____________

____________ ____________

____________ ____________ Product rate ____________

Miscellaneous chemicals ____________

Figure I-6. Dye-range material balance.



Alkalinity

Fabric						
Waste						

Fabric production rate: ____________________

Total water use: ____________________

Total caustic use: ______________ Concentration: __________

Figure I-7. Mercerizer and washer material balance.

Table I-6.–*List of important items for textile in-plant surveys*

Identification of print paste, grease, and solvent wastes for segregation to separate treatment
Identification of sources of chemicals potentially toxic to activated sludge systems (such as dyes, solvents, carriers, or finishes)
Identification of sources of shock loads (such as finishing bath dumps)
Identification of sources of high concentrations of refractory, nonbiodegradable wastes (such as carriers and finishes)
Identification of sources of foam-producing chemicals (such as detergents)
Evaluation of size substitutions
Optimization of countercurrent washes
Evaluation of reuse of weak rinse wastes
Evaluation of segregation of high strength (such as BOD, COD, color, or alkalinity) for separate treatment
Evaluation of processing of caustic wastes for reuse
Evaluation of segregation of dyestuffs (acid, disperse, etc.) for separate treatment
Comparison of hypochlorite and hydrogen peroxide bleaching

Table I-7.–*Example of annual chemical usage, 1972*

Rank	Chemical (type)[1]	Usage	
		Pounds	Percent
1	Carrier NT (B)	331,457	12.540
2	Neutrol #9 (C)	200,064	7.569
3	Aerotex water repellant 95 (D)	136,205	5.153
4	Cap LEV LSP (C)	132,685	5.020
5	Soap OFF 60 (A)	126,708	4.794
6	Acetic acid (E)	124,206	4.699
7	Neoport APO (B)	117,609	4.449
8	Solvecrest RB (A)	110,788	4.191
9	Monosodium phosphate (E)	92,672	3.506
10	Caustic soda (E)	89,673	3.393
11	Dispersing agent (C)	84,887	3.212
12	Avitone F (C)	72,443	2.741
13	Calgon (F)	69,130	2.615
14	Fanapon X70 (A)	58,198	2.202
15	Neoport DPG (B)	51,871	1.962
16	Raycofix NY (H)	48,428	1.832
17	Sanopan DTC (A)	47,227	1.787
18	Formic acid (E)	46,779	1.770
19	Sodium hydrosulfite (A)	45,983	1.740
20	Cap Carrier BB (B)	38,867	1.470
21	Ammonium chloride (E)	38,189	1.445
22	Herriton SWD (C)	36,698	1.388
23	Intrawite EBF (G)	30,242	1.144
24	Gluconic acid (C)	27,416	1.037
25	Tanalube RF (C)	24,654	0.933

[1] A = scour; B = carrier; C = dyeing assistant; D = finish; E = pH control chemicals; F = softener; G = fluorescent; H = fixing.

For in-plant sampling, the use of appropriately chosen grab samples is usually sufficient. These samples should be taken during each part of the production cycle, and an estimate or measurement of flow made. Important wastewater characteristics should be measured in each sample, but it is not necessary to perform a full analysis of each sample.

Also, on the day that the process sewers are sampled, a single grab sample should be obtained from the receiving stream and the raw waste for complete analysis.

It should be apparent at this point in the review of the waste survey requirements that there is a significant analytical load to any meaningful survey and that there is a strong emphasis on in-plant production analysis.

Considering the degree of treatment being required of the textile industry, an important key to compliance will be a competent water-quality laboratory to provide both operating and reporting data. If a plant does not have sufficient facilities or staff for this work, then serious thought should be given to acquiring the capability in this early stage to assure maximum familiarity with the wastewater problem. This decision can usually be economically justified in light of outside laboratory costs.

Also, the importance of introducing responsible production personnel at the onset of the water-pollution-control program cannot be understated. This becomes even more important as regulations require consistent removal of virtually all pollutants from the discharge. Soliciting process information and keeping the production personnel informed of the work under way is the best way to develop a program of optimum waste reduction and recycling and to determine how the waste is affected by the operating characteristics of the process and its susceptibility to upset, misoperation, and change.

DETAILED SURVEY

After completion of the initial feasibility study, a decision will probably be made to evaluate, over a period of time, the treatment processes and in-plant control measures selected as the most likely solutions. This additional detailed process evaluation study is necessary to firmly establish the process design parameters and should also be utilized to gather additional waste characterization and in-plant data.

Ideally, this final survey program should last 1 year in order to observe seasonal variations and production vagaries and to allow time to fully develop and explore alternatives. The elements of this detailed survey are essentially the same as the initial survey, but the intensity, duration, and precision of the various aspects have increased.

The incoming water balance information should continue to be recorded. Water meters will allow for daily measurements. These data should be reported both as gallons per day and gallons per pound of cloth. Similarly, refinement of the sewer balance should be undertaken.

At least one permanent flow measurement station should be built to continuously record total plant effluent volume on a daily basis. This equipment should provide a 24-hour graph of flow. If the wastewater volume can justify the expense, multiple stations should be installed to measure flow from each department or division. An example of station locations is shown in figure I-8.

As part of this station, a permanent sampling station should be installed to provide a single daily-flow composited sample. Periodically, this composite can be removed once every hour to evaluate variations in waste strength.

A program of daily analysis of the process sewer waste should be instituted. This program should attempt to frequently monitor critical wastewater characteristics and to regularly measure all necessary characteristics. A recommended analytical schedule is presented in table I-8.

Both flow and contaminant data should be reviewed frequently to determine trends and to change the direction of the work as required.

Production data should also be recorded during this period. A history of chemical and dyestuff usage should be maintained on a monthly basis. A history of production volume by major product lines should be maintained on a weekly or daily basis. Changes in production chemicals or processes should be noted.

Sampling and analysis of both raw water and receiving-stream water should continue once every 2-4 weeks. Raw-water samples should be taken on days when complete sewer analyses are scheduled.

If possible, any planned segregation of sewers should be accomplished during the study to make sure that valid data are obtained. Frequently, paper "substations" are not duplicated in the field because complete segregation is not always possible.

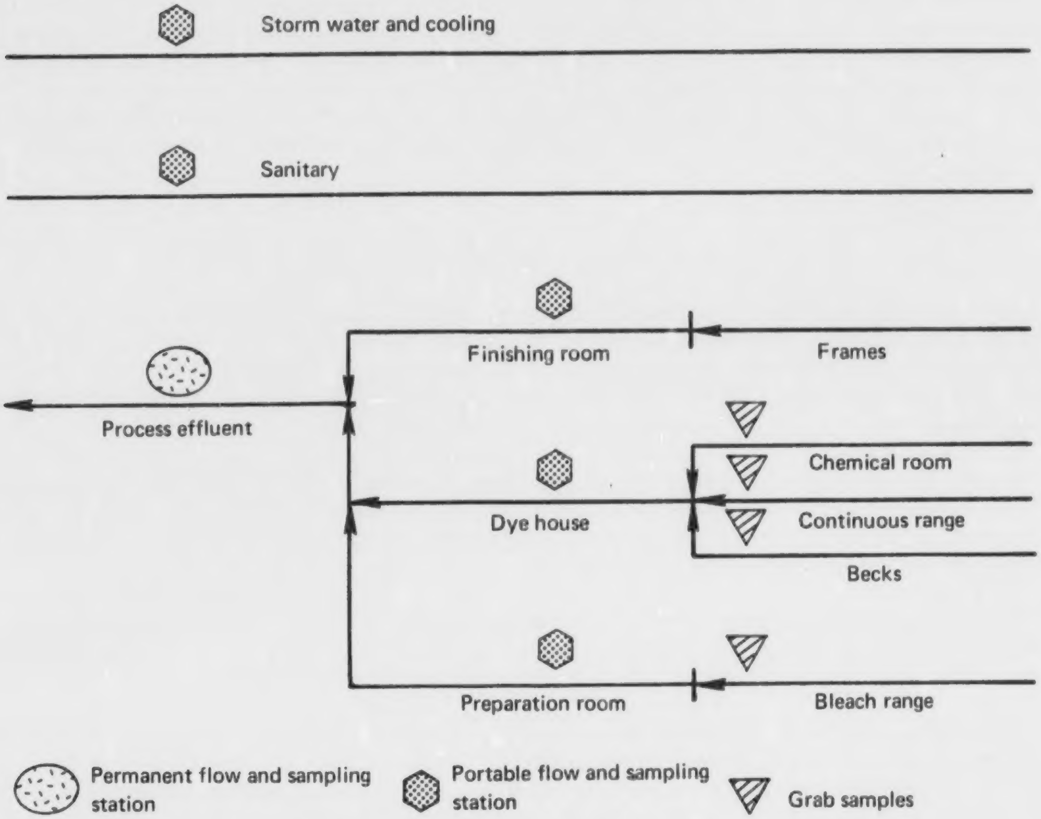

Storm water and cooling
Sanitary
Finishing room
Frames
Process effluent
Chemical room
Dye house
Continuous range
Becks
Preparation room
Bleach range
Permanent flow and sampling station
Portable flow and sampling station
Grab samples

Figure I-8. Detailed survey sampling points.

Table I-8.–*Detailed survey analytical schedule*

Characteristic	Main process sewer	In-plant sewer	Cooling, sanitary, raw, and stream water
Flow	0	3	4
BOD	2	4	4
COD	2	3	4
Suspended solids	2	4	4
Dissolved solids	3	4	4
pH	2	4	4
Temperature	1	4	4
Dissolved oxygen	1	4	4
Color	2	4	4
Turbidity	3	4	4
Nitrogen	3	4	4
Phosphorus	3	4	4
Detergent	3	4	4
Phenols	3	4-5	5
Alkalinity	2-4	4-5	4-5
Metals	3-4	4-5	5
TOC[1] (or other instrumented method)	4	4-5	5

[1] TOC indicates total organic carbon.

Note.–0: measured daily; 1: measured in place; 2: measured 3 times per week; 3: measured 1 time per week; 4: measured 2 times per month; 5: measured 1 time per month.

The in-plant survey portion of the detailed survey is critically important. At this point, a significant amount of time should be spent reviewing the environmental impact of each waste source and each major chemical used.

It is especially valuable to observe production machinery under various conditions to determine the validity and variability of the data being collected and to determine the impact of problems and malfunctions, since these usually result in higher waste loadings.

This is the time to scrutinize each segment of each production process to determine if the minimum amount of water and chemicals are being used. Also, alternate chemicals need to be evaluated to determine if production goals can be met with a lower environmental impact. The production machinery itself should be reviewed to determine if the cost of alternate equipment would offset the cost of treating the pollutants generated. It is helpful at this point to begin to break down the projected water-pollution-control cost by department to make economic justification of charges easier to determine.

This is also the time to police the plant to eliminate unnecessary uses of water and to institute a program of prevention of accidental pollution. Typical examples are presented in table I-9.

As in the case of sewer segregation, any significant process changes should be made during the course of the study to insure that accurate and updated data are obtained.

Table I-9.—*Listing of miscellaneous pollution sources*

Eliminate running hoses
Replace or repair leaking pumps, compressors, heat exchangers, or other similar equipment
Install water meters and level controls on process equipment to minimize water use
Dike chemical storage areas and make sure chemical-handling equipment is designed to minimize accidental spillage
Institute dry clean up of dry-chemical spills
Institute a reporting system for chemical spills and other extraordinary discharges to the plant sewer system
Evaluate wet air-pollution equipment for change to dry equipment
Evaluate maintenance and equipment-cleaning chemicals for pollution potential
Evaluate boiler and cooling tower chemicals for pollution potential

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DATA EVALUATION

At the completion of the detail survey, a sound foundation exists for establishing the basis of a treatment system design. The longer the detailed study, the more variation in wastes will be seen. This information on variation is critically important. The treatment plants that will be required to meet new standards will have to achieve very high performance standards. Yet, unlike other typical chemical processes, there is limited control over the raw material to this plant.

With an accumulation of data, the evaluation of the data is done statistically. Probability and daily pollutant load curves, similar to those shown in figure I-9, allow for the interpretation of this large volume of information.

Wastewater data should be evaluated not only by themselves, but also in terms of the production. Data should be presented as gallons or pounds per unit of total production. If possible, production data should be broken down into major categories and a computer correlation made with daily wastewater data broken down to give gallons or pounds per unit of each product line or production area.

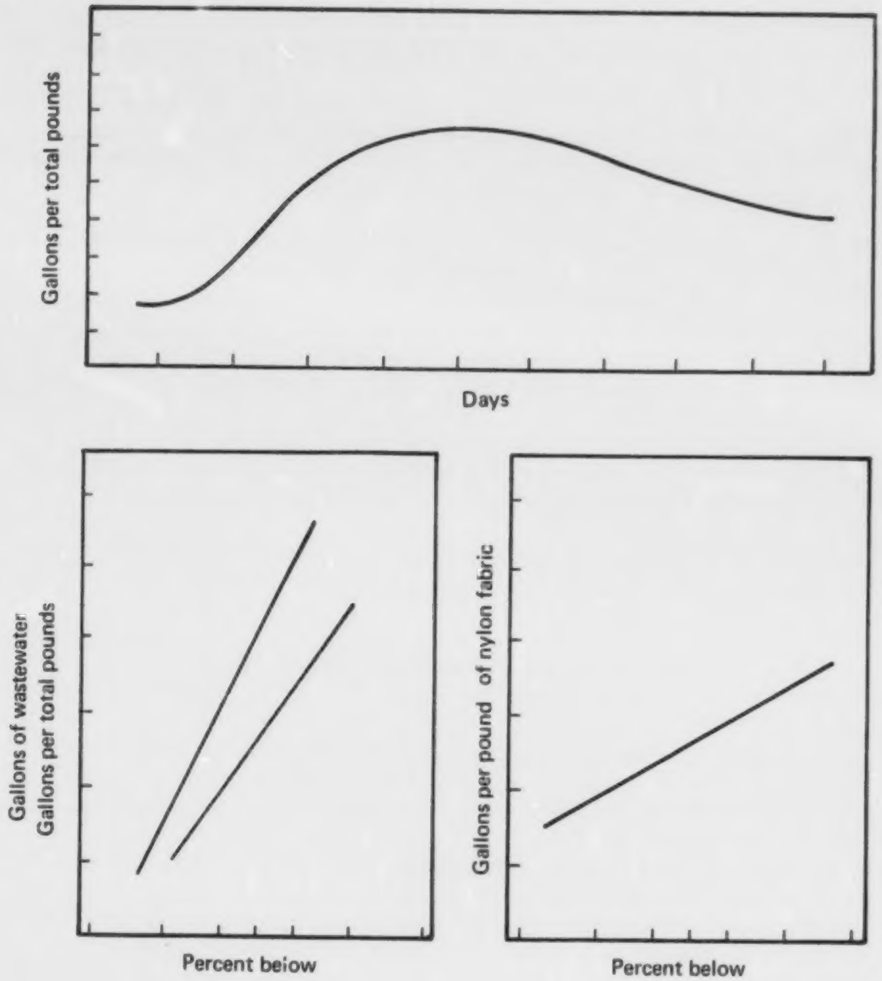


Figure I-9 Graphical results of detailed survey.

The data collected should also be interpreted in terms of the production processes and chemicals used, and separate evaluations should be made, when possible, for the various periods.

The final step in the data evaluation segment is to correlate the information on present operation with the estimated capacity of the present or future manufacturing facility. The more production segments that can be used to compile the estimate, the better the validity of the design basis.

CONTINUING MONITORING

In addition to providing the basis for a rational wastewater-treatment-system design, the information collected during the detailed survey will serve as a standard in monitoring the treatment facility for operational purposes and in comparing alternate production methods and chemicals.

The importance of involvement of production personnel is strongly emphasized. Each supervisor should be aware of his department's portion of

- The pollutants in pounds per pound of product
- The flow in pounds per pound of product
- The treatment cost in pounds per pound of product
- The environmental effect of production upsets
- The environmental impact of major production chemicals

Since textile mills are users of a wide variety of chemicals and since product lines regularly change, there is a continual change in the chemicals found in the sewer. It is imperative that in addition to production characteristics, the environmental characteristics be considered in evaluating a new chemical. During the detailed survey, the pollution potential was determined for important chemicals. In the continuing survey, these characteristics are recorded for all chemicals. Also in the detailed survey, brief treatability studies on the major chemicals may have been done; this work should be continued. An example of the data that might be collected is given in figure I-10. This information will serve as a standard for comparing alternate chemicals.

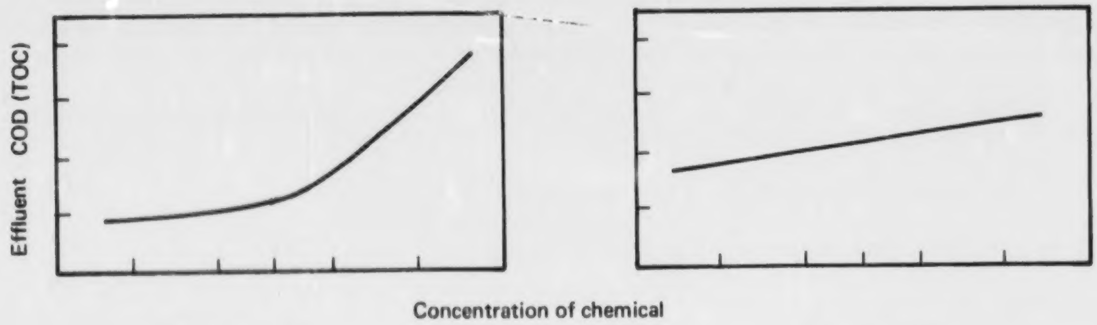
Any preliminary survey is incomplete without an analysis of the impact of the discharge on the receiving stream. First, stream flow records should be obtained from the U.S. Geological Survey in order to develop critical flow values for various periods during the year. Second, information on quantity and location should be gathered on users of and dischargers to the receiving stream. Third, the receiving water should be completely analyzed, with single, representative grab samples of water above the discharge obtained when the process sewers are sampled. Finally, a single sample of bottom deposit above the discharge should be obtained for examination for basic indicator organisms and for chemical analysis. This later work will indicate the present condition of the stream and its tolerance to additional pollutants.

The advent of industrial discharge criteria would seem to obviate the need for consideration of the effect on the receiving stream, but it should be remembered that many States have or are developing stream criteria that may be more stringent than the Federal guidelines. This is especially important when the discharge is to a stream rather than a large river.

In addition to the upstream sampling and analysis of receiving stream water, a profile of the receiving stream at various stages below the discharge should be examined. This profile should consist of both chemical and biological analysis of the water and the sediment and will serve as a baseline of the stream's condition against which the new charge can be compared. A single bioassay and multiple chemical assays will be necessary for accurate results. Also, static toxicity studies using local species of fish and expected effluent should be performed to determine maximum allowable pollutant concentrations and to verify design discharge criteria.

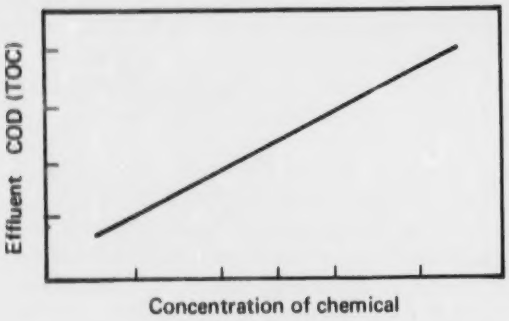
Finally, the continuing survey should monitor individual processes to make sure that unnecessary amounts of water and chemicals are not being used. That is, environmental impact should become a tangible part of the industrial engineering function of process optimization.

COD (TOC) of 1.0 % solution: ______________________________



COD removal by
activated sludge
at MLSS of 3,000 mg/1

COD removal by
coagulation with
400 mg/1 alum



COD removal by
carbon adsorption
with 3.0 lb/1,000 gal

Figure I-10. Typical data for determining treatability of process chemicals.

Chapter II

MAJOR SOURCES OF WASTE*

The major sources of waste from textile operations include process effluents, which can first be related to the following eight categories of textile wastes chosen by the EPA:

- Wool scouring
- Wool finishing
- Greige goods mills
- Woven fabric finishing
- Knit fabric finishing
- Carpet mills
- Stock and yarn dyeing and finishing
- Specialized finishing

Obviously, this system of classification does little to indicate specifically where the chief sources of water pollution within the industry are located. However, this classification system does function to isolate wool scouring as the area with the highest raw waste discharge concentrations in terms of 5-day BOD (BOD_5).

It should be pointed out that generalizations for characterizing wastes within the industry can often have little specific relevance. The reason for this is that textile wastes are extremely diverse. The great variety of dyes, chemicals, and materials removed from textile fibers result in a complex waste mixture that varies in composition from minute to minute depending on the unit processes and operations. Such equipment can be batch types and/or continuous types. This means that at any one sampling, one must consider the chemicals used, the fibers processed, the fabric weight, the processing performed, the equipment used, and the arrangement of the equipment. Furthermore, seasonal variations occur because many plants work on materials that are ordered at certain seasons, such as rain wear or fashion prints.

In the description of major waste loads that follows, consideration is given to the range of compositions that might occur and that has to be interpreted with a knowledge of the conditions at any individual plant.

CHARACTERISTICS OF TEXTILE WASTE LOADS

Masselli and Burford[1] first classified textile pollution sources on the basis of predominant fiber. They surveyed wastes from cotton, wool, and synthetic-fiber processing. Results from their studies showed that pollution loads originated from two sources: natural fiber impurities and process chemicals. Grease scouring woolen mills contributed 50 percent of the total BOD load from natural impurities. In all other plants, natural impurities contributed less than 30 percent of the total BOD load. It is apparent from their studies that process chemicals contribute the greatest pollution load from textile mills.

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*Prepared by Michael S. Bahorsky of the Institute of Textile Technology, Charlottesville, Va.

The data in table II-1 give a comparison of expected waste loads from natural impurities of various fibers with those from process chemicals used. It is obvious that very little can be done to improve the waste contribution from natural impurities, but the range of BOD contribution from the process chemicals indicates that chemical substitutions might improve at least the BOD picture significantly for someone on the upper extreme of the range.

Little[2] provided an interesting example from a cotton bleachery, which gives some idea of the magnitude of the disposal problem. About 4-7 percent of the weight of cotton fabric can be scoured from the fiber. About 4-6 percent more comes from the warp starch size that is removed. This gives about 10 percent of the weight of the fabric to contaminate waste liquors. A bleach works handling 1,000 tons of fabric a year would have to deal, therefore, with 100 tons a year—2 tons a week—of *waste* organic matter.

An approach used in a report series issued by the FWPCA (now EPA) in September 1967, entitled "The Cost of Clean Water," gives a more specific breakdown of pollution load contributions (see tables II-2, II-3, and II-4). (It should be noted that in this report, as in various other survey reports, much information presented is taken from the series of reports prepared by Masselli and Burford.)

The data presented in table II-2 are based on the estimate that the average production of wool scouring and finishing mills is 3,000 pounds per day of finished wool cloth. The daily waste contribution by process for a cotton plant producing 20,000 pounds of cloth per day is shown in table II-3. Again, it is emphasized that a specific plant on a particular day could deviate widely from the figures shown. Table II-4 provides ranges of quantities of pollutants produced from a plant arbitrarily producing 10,000 pounds per day of manmade fiber cloth.

The area of manmade fiber waste characterization is probably the most complex to provide with a typical example, since many manmade fibers are often blended with cotton and wool. In table II-4,

Table II-1.—*Anticipated waste load ranges from processing various fibers* (*pounds BOD per 1,000 pounds cloth*)

Fiber	"Natural" impurities	Sizes, oils, antistats	Scouring	Dyes, emulsifiers, carriers, etc.	Special finishes, waterproof, etc.	Total
Cotton	30-50	5-100	5-60	2-80	2-80	44-370
Greasy wool	200-300	2-90	[1]15-150	5-100	2-80	[2]219-720
Scoured wool	10-20	2-90	[1]10-150	5-100	2-80	29-440
Rayon	3-7	5-60	5-50	2-50	2-80	17-247
Acetate	3-7	5-60	5-50	2-50	2-80	17-247
Orlon	3-7	5-60	5-50	5-100	2-80	20-297
Nylon	3-7	5-60	5-50	2-50	2-80	17-247
Dacron	3-7	5-60	5-50	30-600	2-80	45-787

[1] High value includes soap used for fulling also.

[2] If grease and suint are removed by solvent extraction, this load may be reduced by approximately 200 pounds.

Source: Masselli and Burford, "Pollution Sources from Finishing of Synthetic Fibers," 1956.

Table II-2.—*Daily waste quantities from wool processing*

[3,000 pounds per day production]

Process	BOD, pounds	Gallons
Scouring	680	6,200
Dyeing	31	9,300
Washing	198	130,000
Carbonizing	6.2	49,600
Total	915.2	195,000

Table II-3.—*Daily waste quantities from cotton processing*[1]

Process	Approximate percentage of cloth treated	Wasteload, lb/day for plant producing 20,000 lb/day			Wastewater volume, mgd
		BOD	SS[2]	TDS[3]	
Desizing	95	1,100	570	1,000	0.05
Scouring	100	1,050	431	1,300	0.09
Bleaching	100	150	100	700	0.09
Mercerizing	35	50	15	200	0.08
Dyeing	50	600	250	700	0.40
Printing	14	150	34	200	0.04
Total		3,100	1,400	4,100	0.75

[1] Note that the wastewater volume contributed by the dyeing operation is 52 percent of the total wastewater volume.

[2] SS indicates suspended solids.

[3] TDS indicates total dissolved solids.

Table II-4.—*Daily waste quantities from manmade fiber processing*

Process	Fiber	Thousand gallons	BOD, pounds	SS, pounds	TDS, pounds
Scour Nylon	Nylon	60-80	300-380	200-400	300-500
	Acrylic	60-80	450-900	250-500	120-200
	Polyester	30-50	100-200	50-150	250-350
Scour and dye	Rayon	20-40	480-730	0-30	250-390
	Acetate	40-60	410-590	-	-
Dye	Nylon	20-40	70-130	10-200	200-340
	Acrylic	20-40	20-400	20-420	60-90
	Polyester	20-40	230-1,380	50-200	300-2,000
Salt bath	Rayon	5-15	0-30	-	200-2,000
Final scour	Acrylic	80-100	120-250	20-60	40-120
	Polyester	20-40	150-250	30-70	100-500
Special finishing (optional)	Rayon	5-15	20-800	30-1,000	30-1,000
	Acetate	30-50	20-800	30-1,000	30-1,000
	Nylon	40-60	20-800	30-1,000	30-1,000
	Acrylic	50-70	20-800	30-1,000	30-1,000
	Polyester	10-30	20-800	30-1,000	30-1,000
Total	Rayon	30-70	140-2,400	200-3,000	200-3,000
	Acetate	70-110	140-2,400	200-3,000	200-3,000
	Nylon	120-180	140-2,400	200-3,000	200-3,000
	Acrylic	210-290	170-2,900	250-4,000	250-4,000
	Polyester	80-160	420-7,800	300-6,000	300-6,000

a high BOD is indicated for polyester dyeing. This is because of the contribution from high-BOD carrier compounds. The BOD_5 of various polyester dyeing carriers is shown in table II-5.

The data in tables II-6, II-7, and II-8 are similar to the preceding data but are somewhat more detailed. These tables are included because they are condensations of various studies that have appeared over the years. Wide variations from values appearing in some instances support the fact that although the tables indicate trends, they often will not correspond with individual analyses. (To further guide in the understanding of where major waste loads occur within the textile industry, tables A-1 to A-12 in appendix A include information taken from the literature.)

To obtain an even more precise understanding of the waste loads contributed by a process, as well as how the same process might differ in wasteload, tables II-9 and II-10 are provided. The data in table II-9 show that when starch-sized cotton goods are desized by an enzyme, everything that goes onto the goods comes off, and more. In this case, natural impurities, as suspended solids, contribute to the final BOD output.

If, instead of using starch sizing, polyvinyl alcohol is used, then BOD output is reduced 95 percent (table II-10). It is most important to note in this illustration that the price paid in reducing BOD output is reflected in increased total dissolved solids. Also, not indicated in this illustration is an increase that can occur in effluent COD values. The point to be made in this single and relatively simple example is that one must attempt to cautiously consider all the factors in arriving at a desired result. Having mentioned COD, which is now an established parameter, it should be said that previously very little data had been collected on COD values, making the absence of such information conspicuous.

How the individual chemicals in a vat dyeing of 100 percent cotton fabric contribute to the pollution load is shown in table II-11. Note that the dyestuff exerts no BOD_5. Alternative oxidizing methods demonstrate means of circumventing toxic chromate in the effluent.

The wasteload contribution from vat and disperse dyeing of 50/50 polyester/cotton is given in table II-12. The large contribution of BOD output from the carrier should be noted. The range of wasteload contributions that can be obtained from scouring and piece dyeing polyester knits is shown in table II-13.

Carpet-manufacturing wastes will have characteristics similar to those from an integrated textile mill. (See appendix A, table A-13.) A plant providing backing will have a special problem with latex wastes, which are usually best segregated and treated with chemicals before biological treatment.

Table II-5.—*BOD loadings of polyester dye carriers*

Carrier	BOD	
	ppm	lb/1,000 lb cloth
Orthophenylphenol (most used)	6,000	180
Benzoic acid	27,000	810
Salicylic acid	24,000	720
Phenylmethyl carbinol	19,000	570
Monochlorobenzene (toxic)	480	14

Source: John J. Porter et al., "State of the Art of Textile-Waste Treatment," EPA Pub. No. 12090 ECS, Clemson University, Clemson, S.C., 1971.

Table II-6.—*Pollutional loads of wool wet processes*

Process	pH	BOD		Total solids, ppm	Volume, gallons
		ppm	lb/1,000 lb cloth		
Scouring	9.0-10.4	30,000-40,000	104.5-221.4	1,129-64,448	5,500-12,000
Dyeing	4.8-8.0	380-2,200	9.0-34.3	3,855-8,315	1,900-2,680
Washing	7.3-10.3	4,000-11,455	31-94	4,830-19,267	40,000-100,000
Neutralization	1.9-9.0	28	1.7-2.1	1,241-4,830	12,500-15,700
Bleaching	6.0	390	1.4	908	300-2,680

Table II-7.—*Pollution effect of cotton-processing waste*

Process	pH	Wastes (ppm)		Gallons waste per 1,000 pounds goods	Pounds BOD per 1,000 pounds goods	Pounds total solids per 1,000 pounds goods
		BOD	Total solids			
Slashing, sizing yarn[1] .	7.0-9.5	620-2,500	8,500-22,600	60-940	0.5-5.0	47-67
Desizing	—	1,700-5,200	16,000-32,000	300-1,100	14.8-16.1	66-70
Kiering	10-13	680-2,900	7,600-17,400	310-1,700	1.5-17.5	19-47
Scouring	—	50-110	—	2,300-5,100	1.36-3.02	—
Bleaching (range) . .	8.5-9.6	90-1,700	2,300-14,400	300-14,900	5.0-14.8	38-290
Mercerizing	5.5-9.5	45-65	600-1,900	27,900-36,950	10.5-13.5	185-450
Dyeing:						
Aniline black . . .	—	40-55	600-1,200	15,000-23,000	5-10	100-200
Basic	6.0-7.5	100-200	500-800	18,000-36,000	15-50	150-250
Developed colors .	5-10	75-200	2,900-8,200	8,900-25,000	15-20	325-650
Direct	6.5-7.6	220-600	2,200-14,000	1,700-6,400	1.3-11.7	25-250
Naphthol	5-10	15-675	4,500-10,700	2,300-16,800	2-5	200-650
Sulfur	8-10	11-1,800	4,200-14,100	2,900-25,600	2-250	300-1,200
Vats	5-10	125-1,500	1,700-7,400	1,000-20,000	12-30	150-250

[1] Cloth-weaving-mill waste (composite of all waste connected with each process).

Some effluent-generating processes in the carpet industry follow:

Yarn Manufacturing

Wool scouring
Stock dyeing
Dkein dyeing
Yarn package dyeing
Space dyeing

Carpet and Rug Manufacturing

Beck piece dyeing
Continuous piece dyeing
Küster system for carpet
Zimmer printing
Bradford printing
Stalwart printing
Deep dye printing
Latex application
Foam application
Vinyl application
Back, top, and warp beam sizing for woven carpet

Some Carpet Plant Products

Yarn
Tufted carpet or rugs
Woven carpet or rugs
Knitted carpet or rugs
Needlepunch carpet

Table II-8.–*Pollutional load of manmade wet fiber processes*

Process	Fiber	pH	BOD		Total solids		Suspended solids, lb/1,000 lb cloth	Volume in gal/1,000 lb cloth
			ppm	lb/1,000 lb cloth	ppm	lb/1,000 lb cloth		
Scour	Nylon	10.4	1,360	30-40	1,882	30-50	20-40	6,000-8,000
	Acrylic/modacrylic	9.7	2,190	45-90	1,874	12-20	25-50	6,000-8,000
	Polyester	–	500-800	15-25	–	25-35	5-15	3,000-5,000
Scour and dye	Rayon	8.5	2,832	50-70	3,334	25-39	0-3	2,000-4,000
	Acetate	9.3	2,000	40-60	1,778	–	1-20	4,000-6,000
Dye	Nylon	8.4	368	5-20	641	20-34	2-42	2,000-4,000
	Acrylic/modacrylic	1.5-3.7	175-2,000	2-40	833-1,968	6-9	5-20	2,000-4,000
	Polyester	–	480-27,000	15-800	–	30-200	–	2,000-4,000
Salt bath	Rayon	6.8	58	0-3	4,890	20-200	2-6	500-1,500
Final scour	Acrylic/modacrylic	7.1	668	10-25	1,191	4-12	3-7	8,000-10,000
	Polyester	–	650	15-25	–	10-50	3-50	2,000-4,000
Special finishing	Rayon	–	–	20	–	3-100	3-50	500-1,500
	Acetate	–	–	40	–	3-100	3-50	3,000-5,000
	Nylon	–	–	10	–	3-100	3-50	4,000-6,000
	Acrylic/modacrylic	–	–	60	–	3-100	3-50	5,000-7,000
	Polyester	–	–	2-80	–	3-100	3-50	1,000-3,000

Source: John J. Porter et al., "State of the Art of Textile-Waste Treatment." EPA Pub. No. 12090 ECS, Clemson University, Clemson, S.C., 1971.

In the light of what has been said concerning the variability of textile wastes, it is doubtful if a truly representative sample can be obtained to accurately show major sources of wastes in a textile plant. A sample taken at one time can easily be different from that taken at the same time the next day. Samples can show the range of composition that exists, but any results must be interpreted with a knowledge of the changing conditions at the specific plant. In reported cases, consultant engineering firms have been misled because strong discharges were disposed of at night and escaped sampling carried out during the day. Even automatic sampling is unreliable unless it is flow related.

It appears that a truer picture of wasteload contributions can be made by obtaining usage figures from inventory sheets over a period of time. This procedure requires that the BOD equivalents of the chemical and the BOD levels to be expected from process liquors (flow rate) be known. Knowing these equivalents and levels and knowing the weight of material and types of fibers treated can give a measure of the material that will be removed in processing. Cross checks by occasional sampling of processes, when appropriate, will give confidence in the use of such a method. This method of estimating pollution loads is perhaps the easiest and most economical way to contribute to an overall pollution abatement program.

REFERENCES

[1] J. W. Masselli, N. W. Masselli, and M. G. Burford, "A Simplification of Textile Waste Survey and Treatment," New England Interstate Water Pollution Control Commission, June 1967.

[2] A. H. Little, "Treatment of Textile Waste Liquors," *J. Soc. Dyers Colour.*, *33*(7), 268-273, July 1967.

Table II-9.–*Enzyme starch desizing of 100-percent cotton-woven goods (60 percent warp)*

[Production basis: 1000 pounds greige goods (containing 5 percent water), starch loading 14 percent based on warp]

Chemical throughputs	Input, pounds	Output, pounds	Unit BOD, lb/100 lb output	BOD output, pounds
Item:				
Starch	84.0	84.0	50	42.0
Fats and wax	4.4	4.4	80	3.2
Oil	0.4	0.4	80	0.3
Enzyme	1.6	1.6	2	–
Salt	2.5	2.5	–	–
Wetting agent	1.0	1.0	–	–
Suspended solids		5	2	0.1
Water		12,500	–	–
Total				45.6
Effluent:				
BOD	45.6 pounds			
Total suspended solids	89.0 pounds			
Total dissolved solids	5.1 pounds			
pH	6-8			
Color	–			
Oil and grease	4.8 pounds			
Toxic materials	–			
Net effluent water	1.5 gal/lb goods			

Source: Industrial Waste Studies Program, Textile Mill Products, May 1971, for EPA by A. D. Little, Inc., Cambridge, Mass., unpublished.

Table II-10.—*Polyvinyl alcohol desizing of 100-percent cotton-woven goods (60 percent warp)*

[Production basis: 1,000 pounds greige goods]

Chemical throughputs	Input, pounds	Output, pounds	Unit BOD, lb/100 lb output	BOD output, pounds
Item:				
Polyvinyl alcohol	48.0	48.0	1	0.48
Wax	2.4	2.4	80	1.92
Oil	–	–	–	–
Suspended solids	–	5.0	2.0	0.10
Water	–	12,500	–	–
Total				2.50
Effluent:				
BOD	2.50 pounds			
Total suspended solids	5.0 pounds			
Total dissolved solids	48.0 pounds			
pH	6-8			
Color	–			
Oil and grease	2.4 pounds			
Toxic materials	–			
Net effluent water	1.5 gal/lb goods			

Source: Industrial Waste Studies Program, Textile Mill Products, May 1971, for EPA by A. D. Little, Inc., Cambridge, Mass., unpublished.

Table II-11.–*Vat dyeing of 100-percent cotton-woven fabric*

[Production basis: 1,000 pounds greige goods]

Chemical throughputs	Input, pounds	Output, pounds	Unit BOD, lb/100 lb output	BOD output, pounds
Item:				
Dye	40.0	1.6	–	–
Sodium hydroxide	50.0	50.0	–	–
Sodium hydrosulfite	35.0	35.0	22	7.7
Dispersant	10.0	10.0	50	5.0
Hydrogen peroxide[1]	2.0	0.1	–	–
Acetic acid	1.7	1.7	35	0.6
Sodium perborate[1]	10.0	10.0	–	–
Sodium dichromate[1]	10.0	10.0	–	–
Acetic acid	5.6	5.6	35	2.0
Detergent	10.0	10.0	50	5.0
Sodium carbonate	10.0	10.0	–	–
Rework				0.4
Water	–	42,000	–	–
Total				19.1
Effluent:				
BOD	19.1 pounds/1,000 pounds greige goods, Nat. avg.			
Total suspended solids	–			
Total dissolved solids	117-127 pounds			
pH	12.5 (0.15 percent sodium hydroxide)			
Color	1.6 pounds			
Oil and grease	–			
Toxic materials	Chromium = 3.5 pounds			
Net effluent water	5 gal/lb goods			

[1] Alternatives.

Source: Industrial Waste Studies Program, Textile Mill Products, May 1971, for EPA by A. D. Little, Inc., Cambridge, Mass., unpublished.

Table II-12.—*Vat and disperse dyeing of 50/50 cotton/polyester knit fabrics including scouring or partial bleaching*

[Production basis: 1,000 pounds goods]

Chemical throughputs	Input, pounds	Output, pounds	Unit BOD, lb/100 lb output	BOD output, pounds
Item:				
Vat dye	20.0	1.0	–	–
Disperse dye	7.5	0.375	5	0.02
Carrier	40.0	40.0	85	34.00
Monosodium phosphate	25.0	25.0	–	–
Dispersing agent	10.0	10.0	50	5.00
Sequestrant	5.0	5.0	50	2.50
Sodium hydrosulfite	25.0	25.0	22	5.50
Sodium perborate	5.0	5.0	–	–
Detergent	12.5	12.5	50	6.25
Natural impurities	25.0	25.0	50	12.50
Rework				2.6
Total				68.4
Effluent:				
BOD	68.4 pounds			
Total suspended solids	–			
Total dissolved solids	189			
pH	12			
Color	1.4 pounds			
Oil and grease	–			
Net effluent water	30 gal/lb goods			

Source: Industrial Waste Studies Program, Textile Mill Products, May 1971, for EPA by A. D. Little, Inc., Cambridge, Mass., unpublished.

Table II-13.—*Scoured and dyed polyester*

[Production basis: 1,000 pounds fabric]

Chemical throughputs	Input, pounds	Output, pounds	Unit BOD, lb/100 lb output	BOD output, pounds
Item:				
Nonionic surfactant	30-35	30-35	3	.1
Anionic surfactant	10	10	80	8
Carrier—*o*-phenyl phenol	60-150	60-150	140	84-210
or trichlorobenzene	60-150	60-150	3	2-5
or biphenyl (atmospheric beck)	60-150	60-150	140	84-210
or butyl benzoate (pressure beck)	15-40	15-40	140	21-56
Disperse dye	5-40	.2-1.5	5	.05
Sequestrant (EDTA)	2.5-5	2.5-5	2	.1-.2
Acetic acid, 56 percent	20	11	35	4
or monosodium phosphate	20-30	20-30	0	0
or monosodium phosphate acetic acid, 56 percent (preferred)	5	3	35	1.5
Soda ash	50	50	0	0
Sodium hydrosulfite	10	10	22	2.2
Water		290,000		

Effluent—calculated:	
BOD	100-225 pounds (atmospheric beck); 33-70 (pressure beck)
Total suspended solids	Indeterminate
Total dissolved solids	80-90 pounds
pH	6-8
Color	Indeterminate
Toxic materials	Orthophenyl phenol, trichlorobenzene
Net effluent water	35 gal/lb goods (average)

NOTES: Data given above refer to disperse dyeable fiber, but are essentially the same for cationic-dyed fiber.

Data refer to polyester knits, piece dyed, using regular or textured yarn. Package dyeing will use the same chemicals, but less water. For woven goods, size must be added—30 lbs sodium polyacrylate; output, 30 lbs; BOD, 0.3 lb.

Allow additional chemical and BOD output for goods to be reworked; assume 3-5 percent of fabric is reprocessed.

BOD outputs calculated from data given in *American Dyestuff Reporter*, pp. 39-42, August 29, 1966. A biodegradable anionic surfactant was assumed.

Source: Industrial Waste Studies Program, Textile Mill Products, May 1971, for EPA by A. D. Little, Inc., Cambridge, Mass., unpublished.

Chapter III

FLOW REDUCTION*

The less water used in the production facilities, the less water that will have to be treated at the waste-treatment plant prior to discharge. In this chapter, some of the areas in which water savings can be obtained will be reviewed and a few examples where J. P. Stevens and Company has made significant water-flow reductions will be given.

Water has been cheap too long and has not been rationed or figured into the cost of the products. We have not had time, with all the other more pressing production-cost savings, to look at the advantages of saving and reusing water. However, as the price of treated water goes up and the price of waste treatment increases much more to meet the current governmental demands, we now have the conditions to encourage water conservation.

Some general areas to consider in water conservation are the following:

- Turn off water to equipment that is not being used. Use automatic shutoffs on hoses, etc.
- Supply only the needed amount of water to a machine. (Don't use 30 or 40 gallons when 20 gallons will accomplish the same job.)
- Modulate water use depending on throughput of material. Use less water for narrower width fabric than for wider fabric.
- Reuse nonchemical treated cooling water. Reclaim by running through a cooling tower or reuse in processes not requiring tap-water quality.
- Chemically treat waters for reuse. Print wastewater can be clarified and returned to wash the blankets and screens of the print machine.
- Steam condensate return.

CASE HISTORIES

Four case histories in which some of the above methods were utilized are described briefly.

Plant 1

A plant with 13-300-pound kiers on stream with no water recovery was using approximately 700,000 gpd. Water supply was limited, pressure dropped, etc.

Five 1,000-pound kiers were added, and a recovery system was activated into a new hot water system under pressure. In addition, the plant restricted water use by placing flow reducers into large lines. Current wastewater is approximately 400,000 gpd.

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*Prepared by Samuel H. Griggs of J. P. Stevens and Co., Inc., Piedmont, S.C.

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Plant 2

Where 30-35 gallons of water were being used per pound of fabric dyed, conservation reduced the use to 18 gallons per pound of fabric dyed. This was accomplished by examining the process and restricting the water use.

Plant 3

In plant 3, there was a reduction of approximately 800,000 gpd going to waste treatment effected by the addition of a cooling tower on nonchemical, treated cooling waters.

Plant 4

In plant 4, there was a savings of 288,000 gpd effected by adding a cooling tower to reclaim air compressor cooling water. As a result, approximately $18,000 per year was saved.

Chapter IV

WATER REUSE*

In the textile industry, there is a fertile area for research in the field of water management and water reuse. The problem in the past has been that too few systematic approaches have been attempted. Almost all industrial water-using operations can reduce their total consumption; textiles are not the exception. Most textile plants use more water than is absolutely necessary, and the use is constantly increasing. With top management backing, large reductions in water consumption can be made. Without this backing, the operating personnel regard suggestions as outside interference and nothing constructive is accomplished. Even with top management backing, it is a slow process.

Water reduction and water reuse, however, are not necessarily synonymous. Water reduction is the use of less water in production, that is, gallons per pound of product. Water reuse, however, is something else; it is the use of the same water more than once. An example would be to use rinse water from one operation for makeup water in a second operation. This results in a reduction in total production water use but does not necessarily reduce the gallons used per pound of product.

There are many questions that require answers before effective water reuse can be accomplished. Some of these are as follows:

1. What level or levels of water quality is available within the plant?
    a. What is the minimum level or levels of water quality actually required for the various dyeing and finishing operations used? Unless the minimum level of water quality necessary for processing is known, no effective program of reuse is practical.
    b. If more than one quality is acceptable or if the minimum acceptable level is lower than the level in general use, what are the economics for using these various levels, including piping changes, storage cost, pumping cost, water-treatment cost, and miscellaneous?
    c. If the water used is purchased water (municipal supplier), then what effect will a large reduction in water use have on your supplier's cost? A reduction in water production usually increases the cost per gallon. What are the economical benefits to you, if any? Do you have a contract with a minimum use required, that is, minimum monthly charge?
    d. Are there processes in which relatively clean washing or rinsing waters could be available for collection and minimum retreatment for reuse at a slightly lower quality level, if a use is found?
    e. What would be the cost for treatment to restore this reusable water in (c) to a level consistent with the minimum acceptable level? Can these costs be related to (b)?
2. What reductions in flows to the waste-treatment plant can be realized if clean rinse water is reused? What increase in load will accompany a reduction in flows?

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3. Can the waste-treatment plant handle this increased organic strength caused by a reduced volume loading?

    a. Are there constituents in this wastewater that can be handled in a dilute solution but when concentrated by water reuse will be harmful in the waste disposal plant?

    b. Can they be replaced in processing without materially affecting quality or production? At what cost? How is this related to cost of treatment to remove them?

4. Are there materials in the waste that can be handled but cause treatment difficulties? Can they be replaced?

5. Are there materials in this waste that leave residues after treatment that may be unacceptable in the receiving stream?

6. Are there processes in which water can be recycled in a closed loop and no discharge made to the sewers? If so, what are the economics, taking into account water treatment and disposal cost?

As a result of these general questions, it can be seen that there are many unknowns and there are several ways to start, depending on how complete an answer is needed. One is to review the processes and water-quality requirements needed and then tailor the uses to the minimum quality requirements for each process. This can involve collecting all clean water for reuse without treatment or with only minimum treatment and operating two water systems.

A less-involved way would be to survey effluents and determine where the clean water located can be reused. This usually means reusing only clean cooling water for rinses. In any event, the minimum water quality for processing needs to be determined by testing before reuse of clean water is attempted.

The problem, then, comes down to two schemes:

1. Reuse of cleaner water without retreatment

    a. Volumes found?

    b. Volumes needed for a particular process where reuse indicates some success?

    c. Is this cleaner water always available? This means both processes—one producing clean water for reuse and one using it—must operate on the same schedule. (This is a most important consideration.) Where do you get water if reuse water is not available? Will this be a manual or automatic operation? Where will cleaner reuse water go if, after piping changes are made, some days it is not needed? The ideal situation is to have more reusable water than needed and waste the excess back to the drain.

2. Reuse of clean water with treatment

    a. Treatment required?

    b. Treated water quality needed and produced?

    c. Storage and handling systems?

In general, if reuse does require treatment, a separate water system will be necessary in most cases. The separate systems would be a drinking and high-quality-use system plus a lower quality service-water system. In some plants that already have a separate drinking-water and service-water system, a third water system may be necessary. It can be noted that this will increase the total water cost as the raw water use is reduced.

CASE HISTORIES

Cooling Water Reuse Without Treatment

Cooling water that does not come in contact with the cloth or have excess added chemicals can be reused directly.

- Cooling water in hydrosulfite operation reuse as indigo wash water
- In printing, cooling water reused to wash blankets or back greiges
- Cooling water as final rinse in dyeing

Treatment for Reuse

Ultrafiltration. There are several Federal grant projects under way concerning reuse of water after ultrafiltration. The reports to date indicate that this can be a practical approach in certain situations. Operation of this type of equipment produces a water in quality only a little below reverse osmosis. This water can be reused anywhere drinking-quality water is used in processing, but the cost can be high. This could be especially appealing, however, in a single dye-shade dyehouse, then dyes and heat, as well as water, could be reused.

Chemical-Biological Treatment. Chemical treatment following biological treatment has been the subject of several research projects also.

- The effluent from a fiber-manufacturing biological-treatment plant was treated chemically, then filtered for reuse in air conditioning and other cooling operations for use in fiber manufacturing.
- The effluent from an integrated textile waste-treatment plant was treated chemically after granular carbon was added into the biological system. This produced water that could be reused in processing.

One of the things that will be noted in the use of chemical coagulants with textile waste is the high consumption required. In general, only certain chemicals seem to work, usually alum and the iron salts alone, or in combination with a high-molecular-weight polymer, alum in the range of 300-700 mg/l and $FeCl_3$ from 500-800 mg/l without a polymer. The use of a polymer will reduce chemical consumption approximately one-third, but requirements will be high in the 3-10-mg/l range. The cost of chemical treatment could be in the range of \$80-\$150 per million gallons in addition to the cost for biological treatment. In general, this means the cost will be \$100-\$150 per million gallons for high-grade biological treatment, plus \$80-\$150 per million gallons for chemical treatment.

The cost of storage and pumping facilities will be in addition to these costs. This reused water would then be blended into and would replace a portion of raw water for processing, keeping in mind that there will be an upper limit on dissolved solids that can be tolerated.

This could be especially appealing, however, in a single dye-shade dyehouse; then dyes and heat, as well as water, could be reused.

Reuse of water in processing can be carried out successfully from an engineering and production standpoint; however, the main objection to date is cost, which will be two to three times the present one. There does not seem to be any means of reducing this figure to what is considered a more reasonable level. The approach has been to try and also tc recover heat or production chemicals to offset the higher figure.

Chapter V

WASTE SEGREGATION*

Waste segregation has been practiced in the textile industry for many years. The segregations that have been generally used were those that enabled the industry to recover something of value that was being discharged in the waste. This chapter discusses the segregation and recovery practices that have been used at Cannon Mills Company.

Heat recovery is an item that has been in use at Cannon Mills for over 40 years. A dual water system was developed for the bleachery and provided a means of reuse of hot water that was discharged from the steam plant.

Cannon Mills Company began its waste-treatment program in 1953. After the waste survey was completed and evaluated, it was evident that segregation of the wastes at the bleachery would provide the most economical treatment for the waste.

The first step in this program was the construction of three pipelines to the waste-treatment-plant area. One pipeline collected the desizing wastes and transported them to the plant for immediate treatment. The second pipeline collected the highly alkaline wastes and transported them to a storage lagoon at the treatment plant. The third pipeline collected all of the remaining wastes from the bleachery. These additions were completed in 1955. Operating efficiencies at the waste-treatment plant were greatly improved, since it was possible to control the pH continuously.

A dye plant was constructed for continuous dyeing of towels and sheets, and a system to segregate the dye wastes was provided at that time. All of the hot waste waters were collected and screened prior to heat recovery units. The heat recovered by these units saved the company approximately $600 per day. They also delayed construction of an additional steam plant for 5 years.

Three additional raw-water pipelines were made available to the waste program in 1965. These pipelines provided a means for planning further segregation at the two dye plants.

Stream standards had been changed and now required a much higher degree of treatment. Additional facilities that were designed to provide 95 percent treatment efficiencies were constructed from 1967 to 1972. Included in this construction were four concrete holding tanks used for storage of wastes to improve weekend operation.

Two tanks are used for dye-waste storage and are equipped with floating aerators to mix the waste and also to provide oxygen to the waste. This arrangement provides 3 million gallons of dye waste for the treatment plant when the mill is not in operation. Another tank with 2.6 million gallons capacity is used for caustic waste storage. This provides continuous pH control that is required for high-efficiency operation. The final tank of 2.6 million gallons capacity will be used for the storage of spills and overflows that occur in the bleachery and dye houses.

There are now seven pipelines that are available to the waste-treatment system. These pipelines provide a means for seven different types of wastes to be blended at the waste-treatment plant. The blender is capable of supplying five biological treatment units with any combination of wastes that is desired.

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*Prepared by John L. Brown, Jr., of Cannon Mills Company, Kannapolis, N.C.

Chapter VI

PANEL DISCUSSION ON SUBSTITUTION OF PROCESSES AND MATERIALS

GENERAL CONSIDERATIONS*

Introduction

This panel discussion on the in-plant control of pollution involves the substitution of processes and materials, the results of which will reduce or prevent waste, both in quantity and quality. The resultant overall organic load to the receiving stream will be reduced in poundage, and the hydraulic flow will be reduced in quantity. In order to accomplish this, there are many long-range aspects of the problem and very few short-range quick solutions.

As has been seen earlier, there are certain prescribed steps that must be taken in a plant in order to define the problem. These steps are:

- The waste survey
- Major sources of waste
- Flow reduction
- Reuse of water
- Waste segregation
- Substitution of processes and materials

All of these items are interrelated, but after the first five have been instituted, the last item will continue on ad infinitum. In reference to this last item and before the textile industry is discussed, there are examples in other industries that should be examined.

Metal-Working Industry

In the metal-working industry, certain parts have, until recently, been made into very intricate forms and shapes by machining and/or hand shaping. This produced a part with a high metal-waste factor accompanied by waste machine oils, coolants, and lubricants. Due primarily to the inherent high cost of such an operation and a demand for a higher volume of such parts, metallurgists have developed the powder metallurgy technology. The vast quantities of waste shavings of expensive alloys have been eliminated, and the machining phase is drastically reduced or eliminated by the use of powder metallurgy. The net result is a better product at a cheaper price, with an accompanying high reduction of waste load.

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*Prepared by William J. Day of Davis and Floyd Engineers, Inc., Greenwood, S.C.

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Paper Mills

The manufacture of paper as we have known it over the past few decades has been accomplished by a combination of chemical and mechanical means. For the southern pine tree, the sulfite pulping method gave way generally to the sulfate pulping method. In both of these processes, a high degree of chemical separation or release of the fiber has been employed. This has been accompanied with a very high use rate for water and a high organic-waste production, principally in the form of lignin, terpenes, resin, and fatty acids. The paper industry is presently taking a very hard look at shifting toward more mechanical and less chemical pulping. In addition, different means of chemical pulping are being investigated. These methods show promise in cutting down on the amount of water required and reducing to a great degree the organic waste portion.

The two examples presented previously are broad generalizations of what can be done in other industries to reduce waste. There are some areas where similar approaches *possibly* could be taken in the textile industry.

Nonaqueous Textile Processing

A great deal has been said in recent months concerning nonaqueous textile processes. What has been said has created a great deal of controversy. The American Association of Textile Chemists and Colorists held a seminar in Atlanta in 1972 to review the technology currently in use in nonaqueous textile processing. The general consensus of that seminar was that success has been generally limited to small batch operations concentrating on specialty items. Personnel from within the textile-manufacturing industry have seen very little promise for success in this area in which large, continuous processes are involved. On the other hand, textile-equipment manufacturers are somewhat more optimistic. They feel that research and development will yield processes and equipment for large, continuous, nonaqueous systems that can be substituted for the various unit processes presently being used in the processing of textiles. Therefore, in the nonaqueous-textile-processing field, it is generally conceded that we should proceed with guarded optimism. The present situation in this field compares very closely to the situation in powder metallurgy in the late 1940's. We can see that the powdered metallurgy industry was successful in applying new technology. There is hope here, but our optimism, as mentioned previously, must be guarded in light of reality.

Changes in the Basic Process of Handling the Fiber

Most attendees at this conference are here to learn specifically what basic process can be changed in the many textile-unit processes that will result in savings (capital, time, waste, etc.). I do not believe that many earth-shaking, quick answers are available. It is hoped that during the discussion period, an exchange of ideas may result in someone coming up with a new idea that may change the basic process of handling the fiber. A whole new technology, such as the use of nonaqueous solvents, would be required. Another area that needs some discussion is the elimination of the mercerizing process. Can it be eliminated? This process is the source of high alkalinity in the waste and it needs some radical thinking. Some thought should be given to a radical departure in the types of dye being used. Some progress has been made in this area with high-temperature dye machines, but more thought and time should be spent on this matter. Other chemical substitutions should be looked into. For instance, there has been a gradual shift from starch sizes to the polyvinyl. Starch is treatable in a biological waste-treatment plant. The polyvinyl sizes are difficult to treat. Some attention has been given to their recovery and reuse. There may be some merit in this procedure in technology in order to get the best characteristics of starch and the polyvinyl and still have a biodegradable or recoverable size.

In-Plant Equipment and Flow Changes

In the dyeing and finishing processes, the amount of water used and the scheme of flow within any one process varies widely from plant to plant and is due primarily to the artist who is operating the specific process in question. It is extremely difficult to change these work practices because some of the artists insist that the old method is the only one that will work. This entire line of thinking must be changed. For instance, if it is assumed that a textile dyeing and finishing operation uses 5 million gallons of water per day, then it can be found that an excess of 1½ million gallons per day of water can be readily recycled, reused, or conserved in some manner. The savings of water is about equally distributed between the boil out, mercerizing, bleaching, and dyeing operations. In each instance, water recycle in selected areas accounts for the water savings. This approach has not found favor with plant operating personnel because of apparent quality degradation in the product. The best way to prove that quality will not be affected adversely is to isolate one complete line, modify it, and challenge them to solve the water-conservation problem. They generally find that they can make it work and in so doing, become the authors of changes on the remaining lines.

The new high-temperature dyeing machines offer some areas for water conservation, providing the cycles of operation are controlled very precisely and the excesses of water are cut back. It can generally be found that the recommended wash cycle can be cut back appreciably, and about a 25-percent overall water savings can be realized.

Once the water use has been reduced to the minimum, then other problems can be attacked. In many dyes and dyeing operations, heavy metals, such as chromium, zinc, and copper, are encountered. These metals end up ultimately in the effluent stream. In order to remove them, the streams containing them should be isolated and chemically treated. This treatment is the old standard "redox" reaction between hexavalent chromium and sulfur dioxide, followed by a metal participation at pH 8.5.

Chemical Substitution

Of particular interest today is the removal of heavy metals from the effluent stream. One major source of heavy metals may be from the chromate oxidizer used in certain dyeing processes and operations. The elimination of the chromium problem has been addressed in many ways. Some manufacturers have switched to hydrogen peroxide or the iodates. Both of these process modifications eliminate the chromium, but they may result in product degradation.

WHAT CAN CHEMICAL SUBSTITUTION PRODUCE IN POLLUTION REDUCTION?*

Substitution of Materials

Masselli[1] stated that his data demonstrated the possibilities of substantial pollution reduction through the substitution method were very bright indeed. He expected that the textile industry, as a whole, could quickly reduce its pollution load by 40-70 percent through methods suggested by him in 1956. He felt that with additional research and experience, reductions of 70-90 percent could be obtained. Since 1956, however, additional pollution parameters, such as COD, ultimate BOD, color, and stubborn or refractory chemicals (produced as a result of consumer demands), have probably modified considerably the direction of potential gains achievable from substitution.

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*Prepared by Michael S. Bahorsky of the Institute of Textile Technology, Charlottesville, Va.

Substitution should ideally assume the direction of easily treatable or reusable materials in terms of waste-treatment technology, recoverability, or reuse. Conventional biological systems may at times require low-BOD chemicals to be substituted. Physical-chemical methods will also work more efficiently on certain materials than others. Recovery of carboxymethyl chloride (CMC) size material has been demonstrated over starch and polyvinyl alcohol. Reuse of waters high in certain salts may be tolerated in certain processes at relatively high concentrations before quality is affected.

Masselli[2] pointed out in 1959 that in certain mills, it was the practice to establish scouring and finishing formulations to take care of extreme conditions that may actually occur only 5 percent of the time. Some of these formulations could exceed the required concentrations by safety factors up to 60 percent. Other mills might practice switching similar chemicals based on current price trends. Since it is indicated that process chemicals contribute to the bulk of the textile industries' total waste load, it is suggested that a stable inventory base would be an integral first step as part of an approach to a successful waste control program. Obviously, cutting down excessive use of chemicals will help the pollution problem and costs without affecting the final product in most cases (supervised study is recommended with suitable record keeping).

A useful listing of the BOD characteristics of textile chemicals is published in the August 29, 1966, issue of the *American Dyestuff Reporter*. Examples of chemical consumption and BOD loadings in cotton finishing are given in table B-I of appendix B.

Recovery of CMC Warp Size. Dr. Carl E. Bryan (North Carolina State University) has found that recovering CMC by precipitation with aluminum sulfate (alum) allows reuse of the CMC for four cycles of sizing, desizing, and recovery. Bryan's work shows that it takes about 1 pound of alum ($0.03/lb) to recover 1 pound of CMC. Work on recovery of starch and polyvinyl alcohol has not demonstrated an attractive procedure.

Low-BOD Polyester Dye Carrier. Masselli[1] suggests the use of monochlorobenzene in place of other carriers for dyeing Dacron.

Dye Carrier Reuse or Recovery. Masselli[1] suggests that reuse or solvent recovery of dye carriers should be investigated.

Substitute for Acetic Acid in Dye Bath. Substitution of formic acid for acetic acid in dyeing gives a substantial reduction in BOD and, because of its lower equivalent weight, can give a cut in costs.[3]

Chemical	*BOD equivalent (lb/lb)*
Acetic acid	0.64
Formic acid	0.12

Oil and Lubricant Substitute. Carding oils and antistat lubricants should be replaced by mineral oils with nonionic emulsifiers and other low-BOD substitutes according to Masselli.[1]

Dyeing Wool—Replace Acetic Acid. Masselli[4] demonstrated that dyeing procedures using acetic acid can have 85 percent of the BOD_5 contributed by the acid. If ammonium sulfate is used in place of acetic acid, the BOD can be reduced the full 85 percent. Furthermore, the ammonium content will serve as a nutrient in the activated-sludge process. Of course, the salt content of the waste will be increased.

Wool Fulling. Soap used in fulling can contribute high-BOD levels.[1,3] If detergents or sulfuric acid are used, the table below shows the BOD equivalent of a "hard" detergent (Lissapol N) and that of a "soft" detergent (Empilan KL10).

Chemical	*BOD equivalent (lb/lb)*
Soap (textile flakes)	1.06
Lissapol N	0.06
Empilan KL10	0.72
Sulfuric acid	0

The Surfactant and Foam Problem. Many surfactants, such as the alkylphenol ethoxylate and ethoxysulfate types, are resistant to attack by bacteria found in treatment systems and streams. Consequently, such surfactants continue to foam and pollute natural waters and retard the efficiency of treatment systems. The River Die-Away Test, shown in figure VI-1, indicates what happens using low-bacterial populations as found in natural rivers under laboratory conditions. The Tergitol S series (linear alcohol ethoxylates and derivatives) of nonionics degrade more rapidly than the other surfactants compared. Such a test, coupled with foaming tests and performance application tests (wetting ability, leveling, scouring assistance, bleaching assistance, etc.), will indicate the optimal product for a specific application.

An interesting finding appeared in the February 1972 *American Dyestuff Reporter.* EPA investigators from Athens, Ga., found an eightyfold increase in *p*-nonylphenol between a carpet yarn mill's treatment influent and effluent. Their explanation was that the phenol increase was likely due to biological degradation of the surfactant.

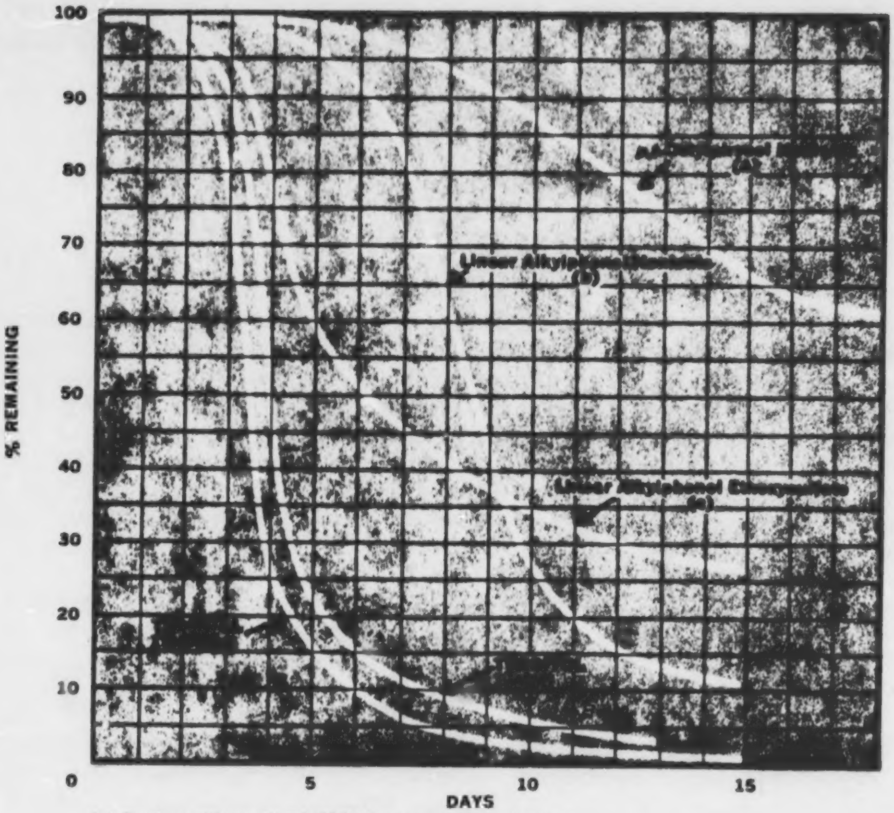
In-Plant Textile Changes at Burlington. In-plant studies to reduce volume and pollution load of wastes within Burlington are summarized below.[5]

Water use was reduced by returning pump cooling water to a reservoir and by better control of the pressure water filter backwash. A program was put in effect to reduce the volume of water used in the various processes. This program evolved slowly because of the reluctance to change or to reduce any component of the operation, such as the elimination or reduction of various washing operations or the reuse of these wash waters in other processes. Reuse of certain wash waters in dyeing has shown promise, but these methods of reuse were not studied further.

The pH of the waste was reduced by the installation of a caustic recovery unit. This unit has resulted in a significant reduction in the pH and hydroxyl alkalinity, making the waste more susceptible to biological action. The caustic recovery not only reduced the pollutants discharged to the stream, but also was expected to be a good investment by returning reusable caustic soda to the process.

One of the major sources of BOD load was starch used in the warp sizing operation. Because of this, CMC was evaluated as a replacement for the starch, and after nearly 15 months of studies and trials, methods were developed that permitted the substitution in the mill operation. While substitution of CMC for starch sizes resulted in an overall BOD reduction of about 50 percent for the entire mill operation, it was found to be somewhat more expensive than starch, and additional studies were made with combinations of CMC and low-BOD starches in order to achieve the same BOD reduction at a lesser cost of sizing materials. This was successful.

Further studies of chemicals in the plant brought about the substitution of detergents for soaps, reducing the BOD of many individual samples by 70-80 percent. Some finishes were found to have less BOD than others, and although the overall waste volume of finishes was relatively low, substitutions of finishes were made whenever practicable. Certain dyestuffs were given consideration because



(a) Such as, "Igepal" CA-630 (General Aniline & Film); "Polytergent" G-300 (Olin); "Triton" X-100 (Rohm and Haas):

(b) Such as, "Igepal" LO-630 (General Aniline & Film); "Sterox" MJB (Monsanto)

(c) Such as, "Alipal" LO-436 (General Aniline & Film)

NOTE: Nonylphenol derivatives; such as, "Polytergent" B-300 (Olin); "Igepal" CO-630 (General Aniline & Film); "Triton" N-100 (Rohm and Haas); and TERGITOL Nonionic NPX, are similar to the octylphenols in biodegradability.

Figure VI-1. Measurement of biodegradation by the River Die-Away Test. (Anionics by methylene blue; nonionics by cobalt thiocyanate; 20 mg/l initial concentration.)

Table VI-1. *Data reflecting in-plant chemical effects of substitutions*

Item	Before changes	After changes	Reduction
5-day BOD, ppm	410	210	190
pH	11.5-12.0	10.0-10.5	2.0
Total alkalinity, ppm	1,600	560	1,040
Hydroxyl alkalinity, ppm	--	180	--
Carbonate alkalinity, ppm	--	380	--

of low pollutional load, but studies were not carried to completion. Table VI-1 shows some effects after chemical substitutions.

Process Changes

Washing Focus for Water Economy. The greatest potential for improved water economy in the textile industry stems from the use of better washing methods It is suggested that washing machines have not been conventionally designed with water economy as a high priority. In this event, it is likely that more efficient washers can be developed.[4] Rodney-Hunt, manufacturers of the Tensitrol washer, compared their washer with two tight strand washers and suggested that up to 85 percent less water use may be achievable.

Why Use Large Quantities of Water? A British survey[6] asked the question of why large amounts of water were used in certain mills. Two major reasons were identified. First, it was considered necessary to some for technical reasons. Others felt quality suffered if copious amounts of water were not used. Natural reluctance to change might also be added. Perhaps the best way to overcome such opposition is to run carefully supervised trials.

Yarn-Dyeing Plant Cuts Water Use. A yarn-dyeing plant was reported[7] to cut water requirements from 75 to 35 gal/lb by discovering and eliminating waste areas.

Use More Lots of Less Water. A British survey[6] of the processes involved in scouring wool revealed that considerable savings could be made—in one case a reduction from 24 gal/lb wool to 3.3 gal/lb was made by using four or five lots of water at a short liquor/cloth ratio.

Water-Consumption Rule. As a rule of thumb, the shorter the wet-processing sequence, the lower will be the water consumption; the longer the sequence, the greater the consumption.[8] Valid parameters in optimizing a wet process for minimal water consumption include temperature, flow rates, fabric speed, water level, and tank size.

Counterflow Wash Boxes Save Water. Dixit[8] stated that the countercurrent system of washing is readily adaptable in J-box bleaching, since it is possible to do away with storage tanks. A system of pumps with filters and suitable pumps are required.

Bleach-Range Considerations. It has been suggested that if a cotton mill with continuous bleaching, using a caustic saturator-J-box-washer-peroxide saturator-J-box-washer sequence, reused water from the peroxide washer in the caustic washer, up to 33 percent savings in water might be accomplished. Systems using two washers after the caustic and peroxide steps might save up to 60 percent.[9]

Reuse Scour Rinse to Desize. Masselli[4] suggested reusing caustic scouring rinses in cotton mills for desizing. Storing these wastes in tanks can equalize them and allow the high-BOD load to be released evenly to treatment. Such a combined waste could contain 60-90 percent of the BOD in 3 percent of the water volume.

Heat Reclamation Recommended. Masselli[4] suggested that heat exchangers should be used, particularly since reduction in water use usually means an increase in effluent temperature. It has been observed by the EPA that the textile industry widely practices heat reclamation, so the wastewaters sent to treatment plants usually do not present any significant thermal-shock problems.[10]

By simply installing copper piping in the waste lines, some mills have preheated water used in the dyehouse. Meyer[11] suggested that a finishing plant with a wastewater flow of 1,000 gpm and a temperature of 140° F may expect savings in recovered heat from this water that would be equal to 30,000 pounds of steam an hour. He envisioned a plant saving $90,000 a year in 1963. Brown[12] cautioned that screens should be used in cotton-processing plants before heat exchangers.

Reuse Cooling Water. Cooling waters may represent a large volume of relatively pure water that might be collected and reused. Williams[5] reported a plant that returned pump cooling water to a reservoir. Better control of pressure-filter backwashes was established and water use was reduced significantly.

Mercerizing Caustic Recovery. It has been suggested[13] that if there is as much as 400 tons of sodium hydroxide available annually, at a minimum strength of 2 percent, its recovery by evaporation for reuse may be economically feasible. Dialysis, another way to recover caustic, provides a purer solution for reuse but requires more sophisticated control and attention. Souther[14] reported that caustic recovery from a plant reduced the pollution load significantly, increased treatment efficiency, and resulted in treatment facility construction cost savings.

Scouring of Raw Wool and Cloth. The treatment of textile effluents, containing large quantities of grease, presents special problems because wool grease and many of the traditional processing lubricants are not readily biodegraded. Even when recovery of wool grease is practiced, by centrifuging or acid cracking, residual grease present in treated liquor may be as high as 10,000 mg/l and is unlikely to be less than 1,000 mg/l. Additional treatment is still required, therefore, before the effluent can be discharged to a river.

Methods examined in detail at the Wool Industry Research Association for the treatment of effluents such as these have included electrophoresis, dialysis, reverse osmosis, and distillation. These studies have resulted in the development of the Traflo-W process (figure VI-2). The process

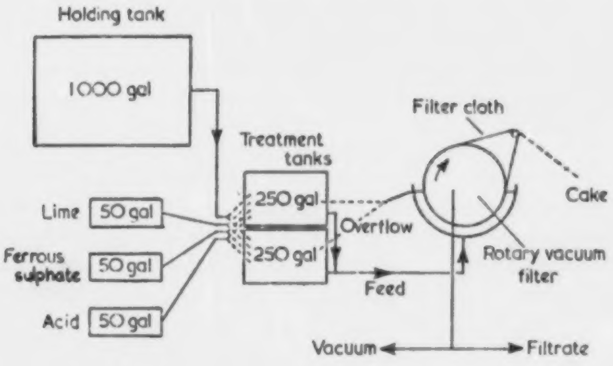


Figure VI-2. Outline of mill-based pilot-scale plant for treatment of piece-scouring effluent.

essentially entails chemical coagulation of impurities, followed by vacuum filtration. At its optimum, it is capable of removing 100 percent of the suspended solids and grease and of reducing the BOD by at least 80 percent. Manufacture of this treatment plant is covered by a license agreement between Wira and Petrie and McNaught Ltd.[6]

Wool-Solvent Extraction. Masselli[1] stated that "if grease and suint are removed by solvent extraction, this load [as shown below] may be reduced by approximately 200 lbs." The use of methylisopropyl alcohol was suggested. It should also be pointed out here that suint is not readily soluble in most common nonaqueous solvents, that is, it is primarily water soluble. Furthermore, wool industry sources[15] indicate that only one known company has survived with a solvent-scouring system, apparently because of high economic factors. Since water systems follow solvent systems, actual pollution savings must be evaluated.

Fiber	*Total pounds BOD/100 lb cloth*
Greasy wool	219-720

Riggs-Lombard Solvent System. John Stewart (Northern Textile Association) described the potential application of a new Riggs-Lombard solvent system for reducing pollution load (in terms of lb/1,000 lb goods), total water consumption, chemicals used (detergents, etc.), labor costs (people required), and time spent (faster than aqueous methods). The 1,1,1-trichloroethane solvent is said to have less than 10 gallons per day loss from a 1,200-gallon-capacity unit. Lost material is not discharged to the atmosphere in this completely sealed system. Used on a wool-nylon-cotton blend fabric, this solvent process of finishing has cut water consumption from 150,000 to 10,000 gpd. A 92-percent BOD reduction in terms of lb/1,000 lb of goods has resulted, although in concentration terms (mg/l), higher values occur.

Solvent Processing. The "State of the Art in Solvent Processing" is documented in the proceedings from the January 1973 AATCC Symposium held in Atlanta, Ga. Perchlorethylene emerges as the solvent of choice. Only solvent scouring and finishing of synthetic knit fabrics is widely practiced and growing. Solvent scouring is practiced in wool finishing to remove spinning, oils, sizes, and tints.[4] Solvent dyeing awaits suitable dyestuffs and equipment. General application of solvent sizing, desizing, scouring, bleaching, and finish chemicals and equipment offer little advantages over aqueous methods. However, developmental work is progressing rapidly enough to clearly envision use of solvent processing in the future.

Automation. Well-designed and properly applied controls, especially in dyeing operations, can bring about reductions in water use, chemicals, and dye use. Gelders[16] reported water use reduced by one-third using punchcard, programed-type, dye-cycle controllers. Instruments that measure percent pickup indicate when cloth is clean, assist with uniform application of chemicals, and provide temperature and pH control are all candidates for consideration in a plant's pollution control program.

Pressure Methods Reduce Carrier Use. In view of the toxic nature and high-BOD potential of dye carriers used in dyeing, it is relevant to point out the pollution advantage gained by the use of pressure-dyeing techniques.

Ammonia May Help. Ammonia for use in desizing, scouring, bleaching, mercerizing, and dyeing of cotton is receiving considerable attention. There appears to be some justification on the surface for the use of liquid ammonia, but lack of information concerning product quality, equipment, corrosion, toxicity, and so on, puts the justification for use of ammonia techniques in the early developmental stage.

Zero Discharge in Dye Operations. Low volume processes, such as microfoam, pad-dry, and solvent dyeing, are still in relatively developmental stages, but should be noted for their pollution advantages.

What Are the Tolerable Limits of Various Substances Before Water Can Be Reused? A comparison of the characteristics of "good" process water, as defined by six different authors, may be made by reviewing tables B-2 through B-7 in appendix B. The variety shown illustrates that it would be ill advised and hazardous for anyone to state unquivocally what the optimum quality for finishing-plant water is. At one time or another, all dyers have been involved in problems caused by unsatisfactory water. It is never easy to recognize the problems or pinpoint the sources of contamination. Experience determines to what level a contaminant is troublesome. Tolerances can only be set with a good knowledge of current operations and processes.

Is In-plant Wastewater Control Economical? A petroleum complex and an organic chemical plant reported the results of their in-plant surveys.[17] The petroleum complex estimated that for a plant to treat 20 mgd with a BOD load of 52,000 lb/day would cost a total of $10 million in capital expenditures. This was activated sludge with vacuum filtration, sludge incineration, and chlorination. In daily terms, this was $720/gpm and $192/lb BOD. Annual operating costs were to be $28.10/gpm and $11.70/lb BOD/day. The curve in figure VI-3 (see table VI-2 for unit cost savings and ratios) shows the effect of wasteload reductions on capital costs of the treatment plant. The slope of the flow curve shows that a unit reduction in flow will cut unit cost by 32 percent. The corresponding figure for BOD is 57 percent.

A flow reduction of 1 gpm would save $288 in treatment-plant costs; lowering the BOD load by 1 pound would save $151. With these data in mind, a team went to work on one of the plant's raw-

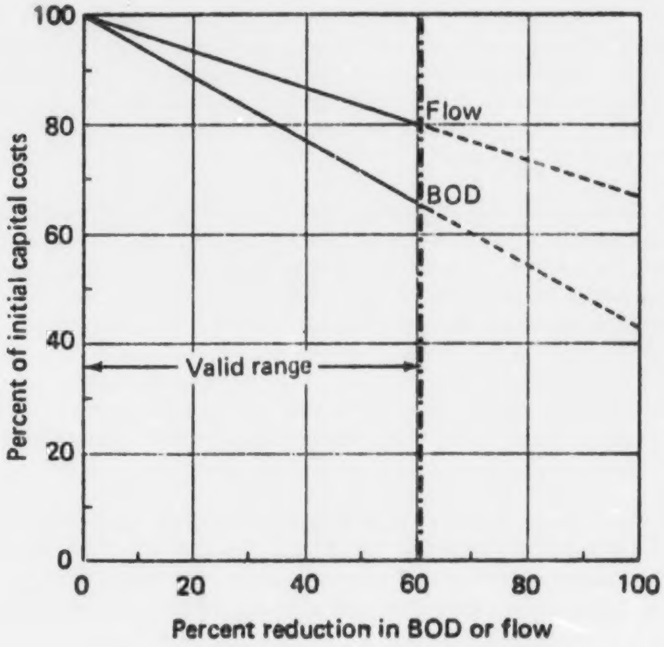


Figure VI-3. Effect of reduction in flow or BOD on capital costs for treatment-plant construction.

Table VI-2.—*Unit-saving calculation*

Item	Flow	BOD
Capital investment	$720/gpm	$192/lb BOD/day
Annual cost (capitalized)	$176/gpm	
Flow ($28.10 X PWF[1])		
BOD ($11.70 X PWF)		$ 73/lb BOD/day
Total unit cost	$896/gpm	$265/lb BOD/day
Unit-reduction savings	$896 X 0.32 = $288/gpm	$265 X 0.57 = $151/lb BOD/day

[1] PWF indicates present-worth factors.

material processes. The total process was shown to have a discharge of 1,700 gpm and a BOD load of about 3,800 lb/day. The following modifications were recommended:

- Increased recycle in the cooling-water system
- Reuse of cooling-tower blowdown
- Elimination of contact cooling for off vapors
- Reuse of water from the overhead accumulator drums, vacuum condensers, and pump glands
- A heat-recovery unit to eliminate a quenching stream
- New turnaround procedures to recover more product and solvents
- Automatic monitoring and alarm instrumentation
- Additional personnel training

When the changes were put into operation, wastewater discharge dropped 85 percent and BOD load dropped 50 percent. The program realized a net savings of $579,000 shown in table VI-3.

The organic chemicals plant was about to install a 2.5-mgd facility to remove 87.5 percent BOD (16,000 lb/day). The system included equalization, neutralization, trickling filter, and activated sludge. Solids were to be landfilled and the effluent chlorinated. Capital cost estimates were $2 million ($1,150 gpm or $125/lb BOD/day—corresponding figures for annual operating costs and maintenance costs were $18.70 and $20). A study showed unit flow reduction would trim costs 35 percent, and a unit BOD lowering would save 30 percent. Anticipated water costs (800 gpm) were to be about $25/1,000 gal.

Management investigated a recirculating cooling-water system. The study determined that some barometric condensers could be replaced with shell-and-tube or air-cooling equipment. Further, a water-cooling tower could tolerate higher organic concentrations. These changes would reduce purchased-water needs to only 26 gpm and lower the waste effluent to about 14 gpm.

As in the previous example, all annual costs were converted to a present-worth basis, using a project life of 7 years and a 15-percent interest rate. The analysis in table VI-4 shows a net savings of $1,263,000.

Table VI-3.—*Savings from in-plant wastewater reductions*

Item	Cost
Flow reduction, 1,424 gpm	$410,000
BOD reduction, 2,000 lb/day	302,000
Water-use reduction	
Treated water (0.24 mgd)	34,000
River water (1.37 mgd)	14,000
Product recovery	14,000
Total in-plant saving	774,000
Engineering	15,000
Capital investment	150,000
Operating and maintenance	33,000
Cost of in-plant control	195,000
Net savings	579,000

Note.—In practice, the savings from a reduction in both flow and BOD would be slightly less than the arithmetic total.

Table VI-4.—*Savings due to in-plant water conservation*
[Dollars]

Item	Cost
Wastewater flow reduction (1.13 mgd)	$ 900,000
Purchase water reduction (1.10 mgd)	410,000
Total in-plant savings	1,310,000
Engineering	5,000
Capital investment	30,000
Annual cost[1]	12,000
Cost of in-plant control	47,000
Net savings	1,263,000

[1] Present worth.

Although these figures represent other industries' problems, the information does reveal that only with an analysis of water reuse and in-plant control can management devise the most cost-effective wastewater system that will comply with the new regulations.

References

[1] J. W. Masselli and M. G. Burford, "Pollution Sources From Finishing of Synthetic Fibers," New England Interstate Water Pollution Control Commission, Boston, Mass., June 1956.

[2] J. W. Masselli, "A Simplification of Textile Waste Survey and Treatment," New England Interstate Water Pollution Control Commission, Boston, Mass., July 1959.

[3] A. H. Little, "Treatment of Textile Waste Liquors," J. Soc. Dyers Colorists, 268-273, July 1967.

[4] J. W. Masselli, "Textile Waste Treatment—Past, Present, and Future," AATCC Symposium, Washington, D.C., May 1973.

[5] S. Williams, "Treatment of Textile Mill Wastes in Aerated Lagoons," Industrial Waste Conference, Purdue University, *16*, 518-528, 1961.

[6] "Effluent Treatment and Water Conservation," CDTRA, Text of the Research Conference, Sherwood, Nottingham, England, Apr. 1971.

[7] *Textile World*, *69*, Jan. 1971.

[8] M. D. Dixit, "Practical Reuse of Water in the Textile Industry," *Colourage I-IV*, Apr. 20, 1972.

[9] V. K. Bajaj, "Water Economy in the Textile Industry," *Textile Dyer and Printer Annual.*

[10] EPA Development Document for Textile Industry Guidelines, August 1973 draft, Effluent Guidelines Division, EPA, Washington, D.C., unpublished.

[11] *Text. Bull.*, *58*, June 1963.

[12] J. L. Brown, "Bleachery and Dyehouse Waste Studies," *Am. Dyestuff Rep.*, *385*, June 6, 1955.

[13] "Industries Waste Guide to the Cotton Textile Industry," *U.S. Public Health Service Publication No. 677*, Washington, D.C., USPHS, 1959.

[14] R. H. Souther, "Waste Treatment Studies at Cluett, Peabody and Co. Finishing Plant," *Am. Dyestuff Rep.*, 13-16, July 28, 1969.

[15] Communication from F. Gross of the Barre Wool Combing Co., Barre, Mass., Sept. 19, 1972.

[16] *Am. Text. Reptr.*, *9*, June 10, 1971.

[17] J. G. McGovern, "Inplant Wastewater Control," *Chem. Eng.*, 137-139, May 14, 1973.

SIZE SUBSTITUTION*

Blair Mills is a combination weaving and finishing mill for towels, wash cloth, and terry cloth, and is located in the small community of Belton, South Carolina. Several years ago, plant wastes were being discharged into a small stream flowing by the mill. The starch wastes quickly became odorous a short distance downstream, especially on warm days. This caused periodic complaints from people living in the community.

In an attempt to correct this problem, a change to a synthetic size, CMC, was made. This inplant change to a low-BOD material for warp sizing solved this off-plant problem. Roughly, 1 pound of synthetic size replaced 2 pounds of starch. Later, a change to PVA-based size was made to reduce sizing costs. Improvements were also achieved in easier cooking and makeup procedures and more uniformity in weaving efficiency with changing humidity conditions and cotton quality.

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*Prepared by James Little of Blair Mills, Belton, S.C.

With a desire to improve the effluent quality of the mill wastes, a modern, activated-sludge waste-treatment system was installed. The 50-percent reduction of sizing solid from starch to PVA permitted a more compact design to meet the BOD effluent design limits. The first testing program, in the fall of 1971, showed that the PVA size was being biodegraded by more than 90 percent. Typical performance data for the waste-treatment system are shown in table VI-5.

This was, perhaps, a little unexpected as it had been assumed by many people that synthetic materials would not be digested by any of the micro-organisms present in the usual activated-sludge waste-treatment system. However, other mills and investigators have shown the biodegradability of such synthetic sizes based on PVA. For example, at the AATCC Symposium on Waste Treatment held in Washington, D.C., on May 22-24, 1973, Du Pont presented a paper that showed biodegradability of polyvinyl-based sizes.

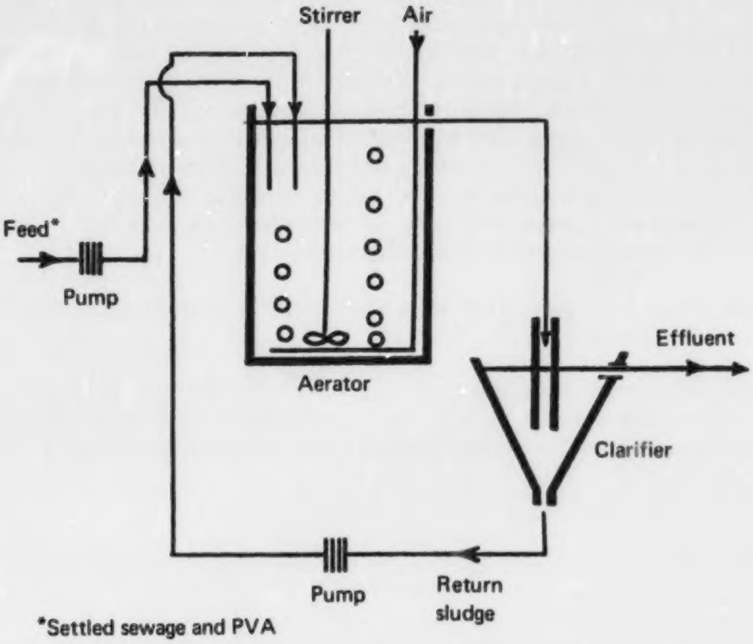
To simulate the effect of introducing PVA into a domestic activated-sludge waste-treatment system, primary settled sewage, containing an added 200 mg/l PVA, was fed continuously into a laboratory scale unit, represented schematically in figure VI-4. The completely mixed aeration tank contained domestic activated sludge not acclimated to PVA. Liquid retention time in the aerator was 6.4 hours. Dissolved oxygen was maintained above 5 ppm and the mixed-liquor suspended solids (MLSS) at 1,000 mg/l.

Initially, the polymer passed through the system unchanged, as shown by the portion of the line A-B in figure VI-5. During this same period, BOD_5 measurements showed on the average that more than 90 percent of the oxygen demand of the domestic sewage was satisfied. This indicated that PVA does not interfere with normal metabolism of these substrates. Analyses for PVA in the feed and effluent in this study demonstrated no removal of PVA during the first 35 days, as shown in figure VI-5. After about 38 days, analyses showed that the concentration of PVA in the effluent was reduced significantly compared with the feed. Apparently, the system had acclimated to PVA, and a population of micro-organisms capable of digesting PVA had been developed. This is represented by the portion of the line B-C in figure VI-5. Biodegradation of PVA was continued for 20 days at an MLSS level of 1,600 mg/l. Under these conditions, 60 percent removal of PVA was obtained. Further work indicated that seeding the laboratory activated-sludge unit aeration tank with two parts of domestic mixed liquors from Blair Mills waste-treatment system, which was acclimated to PVA, eliminated the long induction period, which occurred when the same feed was passed in a nonacclimated system.

In order to test the laboratory acclimation and feeding techniques in the treatment of PVA in textile waste, a joint program was conducted with Cone Mills Research at Greensboro, N.C. Two pilot-scale modified activated-sludge units with extended aeration were operated in parallel, each

Table VI-5.–*Typical performance data for the waste-treatment system*

Item	In	Out	Percent removal
BOD	360	6.4	98.3
COD	2,528	108	95.3
Suspended solids	1,273	32	
Color	500	120	


Stirrer
Air
Feed*
Pump
Aerator
Effluent
Clarifier
Pump
Return sludge

*Settled sewage and PVA

Figure VI-4. Laboratory-scale activated-sludge unit.

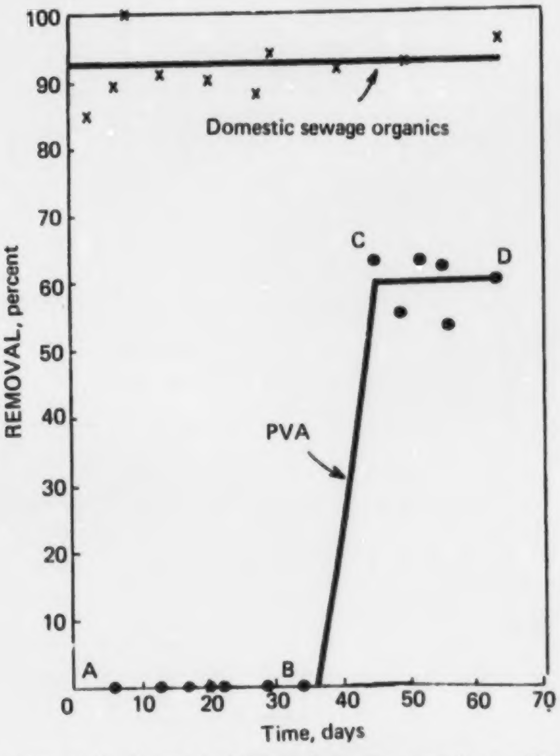


Figure VI-5. Removal of domestic sewage organics and PVA in a laboratory activated-sludge unit.

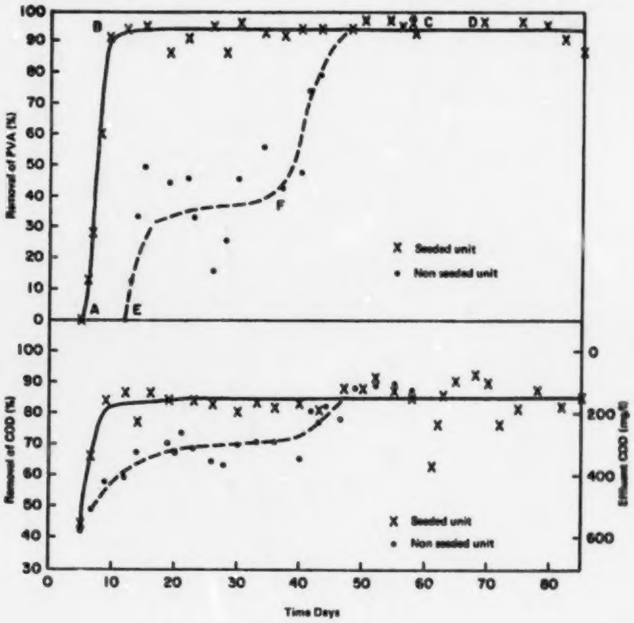
unit being a scaled-up version of the laboratory unit represented in figure VI-4. One unit contained mixed liquors seeded with 10 percent by volume of mixed liquors, taken by Blair Mills waste-treatment plant, which was activated to biodegrade PVA. The feed to each unit comprised Cone Mills' textiles waste containing starch to which 160 mg/l of PVA was added. Operating conditions for the tests are shown in table VI-6. These results confirm those for the lab-scale domestic activated-sludge systems. (The unit seeded with mixed liquors acclimated to PVA showed excellent removal [greater than 90 percent] of PVA within a few days.) This is represented by the line A-B in figure VI-6. This high level of removal was maintained even after a 7-day interruption of the PVA feed, indicating that treatment systems with long solids retention times in the aeration tanks will remain acclimated during weekend and short holiday shutdowns.

In contrast, the removal of PVA in the nonseeded unit was much lower during the first 20 days represented by line E-F in figure VI-6.

The conclusion to be drawn from this and other work is that PVA is apparently biodegradable. If activated-sludge micro-organisms can be allowed to acclimate to PVA, it can be done under conditions attainable in conventional waste-treatment systems, and over 90 percent of the PVA can be removed.

Table VI-6.–*Operating conditions for Cone Mills pilot-scale modified activated-sludge waste-treatment units*

Feed	Mixed liquors	Effluent
BOD_5 400-600 mg/l	MLSS 5,800 mg/l	BOD_5 4-8 mg/l
COD 700-1,100 mg/l	DO 3-6 ppm	pH 8.2-8.5
PVA 160 mg/l	Liquid retention time 33 hours	Suspended solids 10-40 mg/l
pH 8-11		



C-D PVA feed interrupted.

Figure VI-6. Removal of PVA and COD in Cone Mills' pilot activated-sludge units.

REDUCTION OF WASTEWATER FOAMING BY PROCESS-CHEMICAL SUBSTITUTION*

Introduction

One of the most commonly occurring problems associated with the treatment of textile dyeing and finishing wastewaters is excessive foaming. In addition to being unsightly, foam generated during treatment is usually a nuisance to plant operators and may be a frequent cause of complaints from neighbors if blown about by strong winds. Furthermore, excessive foaming may seriously affect the efficiency of wastewater treatment when biological processes, such as activated sludge, that require a large amount of agitation and aeration are used. Interferences with treatment by foam may be particularly critical during startup of a new facility. Presented here is the case history of a waste-treatment situation in which excessive foaming problems had to be solved by in-plant process-chemical change before reliable operation and treatment could be accomplished.

The situation occurred at the United Piece Dye Works plant located at Edenton, North Carolina. The Edenton plant discharges about 1 million gallons of wastewater per day from the dyeing and finishing of synthetic fibers. The wastewater is ultimately discharged to the Chowan River, a large estuary.

The Facilities

In an attempt to provide treatment in compliance with pollution-control regulations, an extended-aeration activated-sludge system was designed and installed. The system consists of a large aeration lagoon with a capacity of 3.25 million gallons, followed by a sedimentation basin equipped with sludge return facilities. The circular aeration lagoon has a 220-foot bottom diameter, a liquid-depth of 10 feet, and sides with a 1 to 1.5 slope. It is equipped with floating, mechanical aerators, and the bottom is sealed with an impermeable, rubberized material. The aeration horsepower ratio in the lagoon at the present time is 135 horsepower per million gallons.

The Problem

When first put into operation, the system had an aeration horsepower ratio of only 44 horsepower per million gallons, much too low to keep significant concentrations of biological solids in suspension. As a result, it was not possible to maintain a lagoon MLSS concentration of more than 350 mg/l, much lower than the 1,500 to 2,000 mg/l needed for proper operation of an activated-sludge system. Consequently, the system performed like an aerated lagoon with a short detention time and a small amount of effluent recycle. In the detention time provided, the low solids concentration was able to achieve a BOD_5 removal efficiency of only 55-65 percent, considerably short of the 85-percent removal required by the State regulatory agency.

As soon as it was recognized that the poor treatment efficiency resulted from the inability of the system to maintain high concentrations of biological solids in suspension, four 75-horsepower aerators were added to the lagoon, bringing the horsepower ratio up to the present level. Unfortunately, the large increase in stirring and agitation greatly multiplied the quantity of foam generated during treatment. The lagoon was soon covered with a layer of highly stable, viscous foam several feet thick. At first, it was thought that the large quantity of foam was just a temporary annoyance that would steadily diminish as the biological solids in suspension increased toward the desired level of 2,000 mg/l. When the average MLSS concentration jumped from a little more than 300 mg/l to more than 600 mg/l the first month, it seemed certain that the foaming problem would be short lived. However, 2 months later, the data showed that the MLSS had not only failed to increase further, it had decreased to an average of slightly more than 400 mg/l.

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*Prepared by Clifford W. Randall of Virginia Polytechnic Institute, Blacksburg, Va.

A close inspection quickly revealed the difficulty. As the biological solids grew in the lagoon, the major portion became entrapped in the generating foam, were floated to the surface, and eventually dumped in a circular pile on the apron surrounding the lagoon. Biological solids were soon stacked 2-3 feet high on the outer edge. The tendency to float the solids out of the lagoon was increased by the sloping sides.

The Solution

The initial attempt at solving the problem consisted of hosing the biological solids back into the lagoon. Although it would temporarily increase the solids and decrease the foam, neither would reach a desired level, and it quickly became obvious that another method of foam reduction was needed. The second solution attempted was the use of defoaming agents. Several defoamers were selected and tried individually for a period of 2-3 weeks each. The defoaming chemicals were added both directly to the lagoon and to the influent waste. It soon became apparent, however, that defoamers alone could not control the foaming. At this point, it was realized that the substitution of process chemicals was the only feasible method of achieving satisfactory wastewater treatment.

While the foaming could not be controlled by the use of defoamers alone, a significant reduction was obtained through the use of one of the chemicals tested. The addition of this defoaming agent was continued throughout the experimentation with process-chemical changes, and it was instrumental in solving the problem. The defoamer selected was a nonsilicone chemical known as Hypochem Defoamer AW-1. Its ability to form a good emulsion was the primary factor that made it superior to the others tested.

To achieve a reduction of the foaming during wastewater treatment through process-chemical substitution, it was necessary to reduce the high-foaming materials in the dye bath. Of course, such reductions could take place only if substitute chemicals with less foaming potential could be identified. Interestingly, excessive spotting of materials was occurring in the manufacturing process at this point in time, and the search for both better quality control and improved wastewater treatment became a joint project. The approach used was basically a trial-and-error technique. Substitute chemicals were tested for compatibility, then added to the dye bath in estimated quantities, and the results were observed. Through this empirical approach, a solution to both problems was achieved.

The chemical changes made were as follows: (1) Tar Remover SW, an 85-percent xylene compound, and its carrier, Tanavol, a nonionic detergent that is a linear ethylene oxide condensate, were replaced with Tanaclean HFP, a high-flash naphtha solvent that contains no toluene, and its carrier, Carolid AL, a biphenyl and ester mix; and (2) TSPP, a tetrahexaphosphate chemical, was removed from the scour bath and replaced with a much smaller quantity of soda ash. The latter change was possible because a dry-cleaning unit had been added.

It was soon apparent that the chemical substitutions had solved the spotting and foaming problems. A summary of waste-treatment-performance data before the chemical changes is tabulated in table VI-7. As the figures show, excessive foam had caused a leveling of the MLSS near 400 mg/l and, consequently, the BOD's removal efficiency was averaging 67 percent. The changes that occurred after the chemical substitutions are shown in table VI-8. The data show that the MLSS concentration increased rapidly after the initial changes and, after that, increased steadily to its present level, which is in excess of 2,300 mg/l. The removal efficiency also jumped sharply, but has increased very little since. However, the true improvement in performance is better illustrated by the effluent BOD's concentrations than by the percent removals, since the influent BOD's also decreased after the chemical substitutions. The data show that the average effluent concentration decreased from 125 mg/l to 65 mg/l, a drop of almost 50 percent. The averages in table VI-8 are for the figures under the dashed line.

Table VI-7.—*Foam-hampered performance data*

Date	Influent BOD's, mg/l	Effluent BOD's, mg/l	Removal efficiency, percent	MLSS, mg/l
11/2/72	400	120	70	620
11/9/72	390	130	67	420
11/16/72	340	120	65	520
11/22/72	390	120	69	540
11/29/72	400	130	68	440
12/4/72	369	141	62	420
12/14/72	360	130	64	420
12/22/72	390	130	67	420
12/29/72	380	120	68	400
1/4/73	400	130	68	400
1/11/73	370	110	70	410
1/18/73	380	120	67	410
Average	381	125	67	

Table VI-8.—*Change in performance with foam control*

Date	Influent BOD's, mg/l	Effluent BOD's, mg/l	Removal efficiency, percent	MLSS, mg/l
2/22/73	370	120	68	440
3/1/73	370	130	65	370
3/8/73	360	130	64	890
3/9/73				1,200
3/14/73	357	70	80	1,280
3/22/73	300	50	83	1,400
3/29/73	329	70	79	1,500
4/5/73	330	75	77	1,670
5/10/73	360	75	79	1,760
6/7/73	340	60	82	2,180
6/13/73	317	52	84	2,299
6/18/73	359	65	82	2,340
6/26/73	362	65	82	2,370
Average	339	65	81	

Economic Considerations

Not only did the chemical changes solve the spotting and foaming problems, they also decreased the chemical costs. A comparison of the cost of the respective chemicals and the quantities required is given in table VI-9. The figures show that the comparative chemical costs decreased by 53 percent. This result was rather surprising, since it was not one of the objectives. Either the

Table VI-9.–*Economic comparison*

Chemical	Unit cost, cents/lb	Applied dosage	Quantity per batch	Cost per batch
Original chemicals:				
Tar remover SW	25.5	3.3 cc/l	20.0 l	$5.10
Tanavol	42.0	1.0 cc/l	6.0 l	2.54
TSPP	11.0	1.0 gm/l	6.5 lb	0.715
Total				8.355
Substitute chemicals:				
Tanaclean HFP	27.5	1.0 cc/l	6.0 l	1.67
Carolid A.L.	36.0	1.0 cc/l	6.0 l	2.18
Soda ash	4.0	0.3 gm/l	2.0 lb	0.08
Total				3.93

improved quality control or the improved wastewater treatment would have justified an increase in chemical costs, but in this case, the change was advantageous from all standpoints.

Chapter VII

PRETREATMENT OF TEXTILE WASTES*

INTRODUCTION

Pretreatment

Pretreatment is defined as operations performed on a waste stream to make it suitable for introduction into another waste system for further treatment. In most instances, the receiving system is a publicly owned municipal or regional sewage-treatment system, but it also may be a private system owned and operated by a mill or group of mills.

The major reasons for pretreatment follow:

- Protection of the treatment process to insure maximum efficiency
- Protection of the receiving system, its structures, and components from damage
- Protection of the health of the public and particularly of the sewage-system personnel
- Satisfaction of legal requirements listed in the local sewer ordinance, State laws, or Federal laws
- Reduction of treatment costs due to industrial-user surcharges

The first three reasons for pretreatment are for protection of the process, the system, and the public. Usually the legal requirements in the local, State, and Federal laws are designed to insure such protection. Consequently the degree of treatment and pretreatment necessary will usually be indicated in the laws.

Local Sewer Ordinance

To qualify for Federal funds, municipalities must have a local sewer ordinance. Most duplicate the model ordinance suggested by the Water Pollution Control Federation in the Manual of Practice No. 3.[1] Many municipal ordinances specify limits for pH, BOD, grease, total solids, and other parameters that textile wastes may exceed, especially after reduction in water use. However, Article V, Section 10, of the WPCF Manual of Practice No. 3 allows special agreements for the discharge of such wastes. Industry should make certain that this section or its equivalent is part of such ordinances when they are enacted.

SEWERAGE-TREATMENT SYSTEMS

The basic component parts of a sewerage-treatment system involve (1) a conveyance system to transport the waste to the treatment system and (2) the treatment system itself. The treatment system is usually composed of a primary portion, which prepares the sewage for biological treatment in the secondary portion of the plant. The component parts of each portion of the system may consist of the following:

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*Prepared by Joseph W. Masselli, Nicholas W. Masselli, and M. G. Burford of the Industrial Wastes Laboratory, Wesleyan University, Middletown, Conn.

- Conveyance system: Pipelines, manholes, wet wells, pumping stations
- Primary-treatment portion: Bar screen, comminutor, grit chamber, preaeration tank, primary settling tank with scum removal device and bottom sludge pumps
- Secondary-treatment system: Aeration tank (or trickling filter), secondary settling tank with sludge-return pumps, chlorination detention tank
- Sludge-handling system: Thickening tanks, anaerobic digestion tanks, aerobic digestion tanks, elutriation tank, filter or centrifuge, incinerator. (The raw sludge, the digested sludge, and the activated (or trickling-filter humus) sludge may be handled separately or mixed together.)

In recent history, the activated-sludge process has become the method of choice for waste treatment. Discussions in this chapter are limited to this method unless otherwise indicated. Occasionally the trickling filter may be used for treatment, but its reduced efficiency during cold weather may cause trouble in meeting future effluent requirements.

POTENTIAL EFFECT OF TEXTILE WASTES

Some of the potential troublemaking sources in textile wastes are listed below:

- Lint, rags, fibers, strings
- Scum
- Foam
- pH
- Alkalinity
- Acidity
- Oxidizing agents
- Reducing agents
- Excessive flow
- Excessive BOD
- "Hidden" BOD's
- Hydrocarbon solvents
- Metals
- High temperature

- Nutrients
- Nitrates
- Spurious biomass (MLSS)
- Dump discharges

Lint, rags, fibers, and strings will clog pipelines, pumps, and moving machinery. In addition, short fibers will pass through the secondary system and occasionally rise to form scum in the secondary settling basin. They also may be collected in foam and cause sticky, odorous deposits along the sides of the aeration tank and the effluent channels.

Scum may cause unsightly stains, odorous conditions, may reduce oxygen transfer and may be difficult to incinerate. It may be formed from soaps, greases, oils, solvents, and resin finishes.

Foam may be produced by both nonbiodegradable and biodegradable detergents. Some foams are unstable and will be readily reduced by water sprays, but others may require special defoaming agents. If not reduced, foam may cause unsightly stains and odorous deposits, and may be blown by the wind to nearby equipment, buildings, and homes.

Acidic pH's below 5.5 should never be allowed in sewage systems, since the cement, concrete, mortar, and metals in the pipelines, manholes, wet wells, pumping stations, pumps, and treatment-plant structures may be corroded. In addition, acidic pH's may deemulsify soaps, fats, and greases to produce sticky gums, which may cause pipe blockage or scum formation. Bicarbonate alkalinity, which usually buffers the pH in the 6.5-8.0 range, will be destroyed, and hydrogen sulfide odors may be intensified if sulfide is present. The pH may be readily adjusted to the 6.5-8.5 range by the addition of lime, caustic soda, soda ash, or ammonia.

Effluents from cotton- and wool-finishing mills are traditionally highly alkaline in the pH 10-14 range because of the use of caustic soda in cotton scouring and mercerizing and soda ash in wool scouring and fulling. The activated-sludge process can satisfactorily treat alkaline wastes, since this process oxidizes the organic carbon in the waste to carbon dioxide. The carbon dioxide reacts with water to produce the acidic carbonic acid; this neutralizes the alkalinity in the waste. Regulation of the waste pH to 6.5-8.5 thus becomes automatic and is being continuously demonstrated by the results from many activated-sludge plants treating textile wastes throughout the country. Probably the only time neutralization may be necessary is when no attempt is made at caustic recovery in mills mercerizing a great percentage of their cloth. It is believed that only 1 mill in 100 may need pretreatment for alkalinity. In some instances, the oxidizing and reducing agents in textile wastes may mutually destroy each other.

Excessive hydraulic flows will cause low detention times in treatment and will cause sludge drag out into the aeration tank and into the final effluent.

Excessive BOD loads will produce zero dissolved oxygen in the aeration tank, and bulking sludge, anaerobic odors, and high-effluent BOD's will result. These "shock" BOD loads may come from dump discharges of high-BOD baths at the end of a run, a shift, a week, or before vacation. Occasionally, processing changes, such as the use of xylene or Varsol in scouring, may cause excessive increases.

Many chemical compounds are apparently nonbiodegradable or slightly biodegradable in the BOD_5 test, but are readily biodegraded by the acclimatized bacteria that develop in the activated sludge after continuous contact with these compounds. In many instances, the actual oxygen demand exerted in the aeration tank will be 10-100 times greater than the demand estimated from the BOD_5 test. If appreciable amounts of such chemicals with "hidden" BOD's are present, the oxygen demand may exceed the aeration capacity of the system. Some of the compounds with hidden BOD's are cellulose, polyacrylic acids, polyvinyl alcohol, naphthalene, and alkyl benzene sulfonate detergents.

Hydrocarbon solvents are composed of carbon and hydrogen solely and represent a concentrated source of BOD. Their BOD_5's are usually 20-100 percent of their own weight, but their theoretical-oxygen demand of 300 percent may be exerted when acclimatized bacteria are present. A 50-gallon drum of such a compound may weigh 400 pounds and exert an oxygen demand of 1,200 pounds in the aeration tank. This contrasts sharply with the average demand of 2-3 pounds per 1,000 gallons for textile wastes. The use of these solvents should be reduced to the lowest amount possible.

Toxic metals (copper, zinc, chromium) are normally used at low levels in textile processing. These are concentrated in the activated sludge at 20-100 times the influent concentrations. Acidic pH's may cause some bacterial kills, since dissolved metallic ions are more toxic than the insoluble metallic hydroxides and carbonates normally present.

High temperatures above 95° F are reported to produce dispersed growths and lower BOD efficiencies.[2] The likelihood of such temperatures will be increased when water use is reduced, and heat reclamation by heat exchangers should be used.

Nitrogen (N) and phosphorus (P) are nutrients required for proper bacterial growths, and BOD:N:P ratios of 100:5:1 are usually recommended. Sufficient phosphate is usually present in most textile wastes, but occasionally ammonia nitrate or another nitrogen source may have to be added.

Nitrates above 22 mg/l in the effluent may be reduced to nitrogen gas and cause rising sludge and scum in the secondary settling tank.[3]

The concentration of activated sludge in the aeration tank is usually maintained at 1,000-3,000 mg/l and is measured by the suspended-solids test. It is normally composed of bacterial bodies (biomass) with 85-95 percent volatile matter and 7 percent nitrogen on a dry basis. Fine sand, metallic hydroxides, paper, textile fibers, and other insoluble organic and inorganic matter will also be measured by this test. If they are present in adequate amounts, they may produce spurious biomass values. Insoluble fibers, paper, and organic compounds will produce spurious volatile matter values, and wool fibers, which have a nitrogen content of 16 percent, will produce spurious nitrogen values. Such sludges will have minimum purifying values, and an inexperienced operator using only the suspended-solids test will not be aware of this.

In spite of the great list of potential troublemaking sources, textile wastes will be efficiently treated by the activated-sludge process when proper design and loading is observed and BOD reductions in the 85-90 percent range can be readily obtained.

PRETREATMENT METHODS

Following is a description of the unit processes having application in pretreatment of textile wastewaters.

Screening

The primary reason for screening is prevention of clogging of the pipes and pumps and also of the comminutors, degritting, skimming, and scraping mechanisms in the system. The major causes of such clogging are rags, strings, or ropes, but individual fibers of 1-2 inches may gather together to form balls or mats, which also clog pipes.

A secondary reason for screening is to remove the bulk of short fibers, since these will pass through primary settling and the aeration tank. In some instances, these small fibers may rise to the surface in the secondary settling basin to form mats or scum, or they may pass through into the final effluent to produce increased suspended-solids concentrations. They also may adhere to the side of the tanks or clog the aerators.

In many mills, screening may not be necessary if ordinary care is tanken to prevent discharge of the rags, ropes, and strings. The few pieces that escape may travel without trouble to the treatment plant and will be removed by the bar screen, which is normally a part of all treatment plants.

If trouble occurs, a bar screen may be installed at the mill. One bar screen with 1- to 2-inch openings is usually satisfactory.

If a considerable amount of fibers are present, screening with finer mesh screens will be necessary. In most instances, 40-80 mesh openings will be satisfactory. The screens may be woven wire or perforated plates and may be stationary, rotary, or vibrating. Mechanical brushes may be used for fiber removal.

pH Regulation

Pretreatment for pH neutralization of acidic wastes (pH's lower tnan 5.5) will usually be required, primarily to prevent corrosion. This may be readily done by the addition of lime, sodium hydroxide (caustic soda), ammonia, sodium carbonate, sodium bicarbonate, or trisodium phosphate. Generally, additions of only 0.25-1.0 pound per 1,000 gallons of effluent (30-120 mg/l) will be needed to raise the pH to the 6.5-8.5 range. If nitrogen addition is required for nutrient value, ammonia should be used, as it will provide both alkalinity and nitrogen. If phosphorus is required, trisodium phosphate should be used.

Increased use of alkaline chemicals in the processes will also regulate the pH. When possible, it should be done to maximize use of the chemical as described.

Acidic effluents were rarely encountered in textile finishing until the advent of polyester knits. When large proportions of knits are being dyed, the acetic acid used in dyeing may produce final effluents in the pH 5.0-6.0 range. Mills with acidic pH's should consider doing some cotton finishing, since the use of sodium hydroxide in scouring and mercerizing will supply the necessary alkalinity.

The simplest means of increasing alkalinity is to pump a concentrated alkaline solution into a drain as far from the effluent end as possible. Controlled dribbling, by means of a constricted valve or pinched rubber tubing, may also be used. A 50-percent caustic-soda solution contains 762,700 mg/l sodium hydroxide (952,000 mg/l $CaCO_3$). Only 63 gallons will be needed to add 60 mg/l $CaCO_3$ alkalinity to 1 million gallons of effluent. The concentrated ammonia solution (57.6 percent NH_4OH) contains 251,400 mg/l ammonia (740,000 mg/l $CaCO_3$). Only 81 gallons will be needed to add 60 mg/l alkalinity (and 17 mg/l ammonia nitrogen) to each million gallons.

Dry lime is the cheapest source of alkalinity, but it must be carefully handled, since the fine powder may be blown all over the premises. Addition of 280 pounds per million gallons will add 60 mg/l alkalinity.

If desired, special neutralization facilities may be constructed. This usually involves a tank or flume allowing a 5- to 30-minute detention with a pH meter controlling the alkali addition. The same controls may be used at an equalizing basin or a primary settling basin if they are part of the system.

Equalization

Equalization—the process whereby the volume or the analytical content of the waste may be discharged evenly throughout the day—may be necessary when batch discharges, intermittent rinsing, or intermittent operation produce wide variations in flow or analytical content. All treatment plants will operate more efficiently if the hydraulic, BOD, and other loads are constant throughout the week.

Optimum equalization may be achieved by discharging all wastes into a pond, lagoon, or tank whose volume is equal to the mill's daily flow. In this manner, a 24-hour detention will be provided, and the analytical contents will be leveled out. If there are wide flow variations, a flow-equalizing method must be devised to prorate the discharge rate. This may be done by means of pumps, siphons, valves, or combinations of these. In most mills, tanks providing only 3- to 8-hour detention times will provide sufficient equalization. In many mills, continuous-processing methods are being used, and equalization will not be necessary.

The major reason for equalization is usually to level the BOD loads. In addition, if the major part of the BOD is being contributed by only one or two washes, only these need be segregated at the source of discharge and stored in much smaller equalizing tanks for discharge over 24 hours and 7 days. This is practicable for the desize and scour wastes in cotton mills, the scour and wash after fulling in woolen mills, and the knitting-oil scour in polyester-knit mills. Usually, segregating a volume equal to only 1-3 percent of the total mill flow will provide equalization of 50-90 percent of the total BOD. Specific methods of equalizing are indicated below under "BOD Reduction."

Equalizing lagoons with detention times greater than 1 day are likely to develop odor problems through anaerobic conditions and the resultant evolution of hydrogen sulfide. This has been known to occur even when the effluent pH is in the 11-12 range. Deep pockets, which collect sludge, will intensify the problem. Duplicate facilities are desirable so that emptying and drying may be done.

Sedimentation

Sedimentation is usually used for BOD and settleable-solids removal, but it is seldom used for pretreatment because the BOD reductions of 10-30 percent normally obtained with textile wastes are not practical. In addition, the original settleable solids in most textile wastes are usually low (below 200 mg/l). However, the settling basin may be a useful site for other pretreatment, when it is available, and may be part of the pretreatment system. It may be used for partial equalization, fiber removal, scum removal, pH regulation, chromium removal, chemical coagulation, sulfide treatment and phenolic treatment. Usually, the tank is sized to provide a 3-hour detention, and scum and settleable-solids removal are mechanically accomplished.

BOD Reduction

In some situations, reduction in BOD loads may be desired to lessen the load on the treatment plant or to reduce costs. Such pretreatment should not be instituted unless a minimum reduction of 25-50 percent in the total mill load will be obtained. Also, if it is to be done, only the major BOD sources should be treated in order to reduce the pretreatment-plant size. From a practicable point of view, this limits cotton mills to the pretreatment of desize and scour wastes, woolen mills to pretreatment of grease scour and the first portion of the wash-after-fulling waste, and polyester-knit mills to the first scour, when the knitting and coning oils are removed.

Although these wastes are fairly high in BOD (500-20,000 mg/l), their content may be increased considerably by reduction in water use and minimum volumes; maximum BOD's will result. To do this, it may be necessary to use counterflow through 10 separate compartments, with squeeze rolls at each compartment. It is believed that 0.3 gallon of water per pound of cloth will produce adequate rinsing, since the processes involved are preliminary processes and not final finishing ones. If further rinsing is required, it may be done immediately following the last rinse, but it must not be used for counterflow.

With controlled water use at this level, a cotton mill processing 100,000 pounds of cloth per day will have to segregate only 30,000 gallons of desize. Its BOD will be 24,000 mg/l. The volume is equivalent to 1-2 percent of the total mill flow, but the BOD contained in it will be equivalent to 50-80 percent of the total BOD. A woolen mill processing 50,000 pounds of wool per day will produce 30,000 gallons of a concentrated waste, with 40,000-80,000 mg/l BOD, equivalent to 90 percent of the total BOD in 1.5 percent of the total volume. A polyester-knit mill processing 50,000 pounds per day will produce 15,000 gallons of a concentrated waste with 24,000 mg/l coning and knitting oils. Its BOD will be approximately 2,400-24,000 mg/l, depending on the specific oils used.

These wastes may be equalized over 24 hours and 7 days to reduce the average BOD load and the size of the treatment plant, if a large enough storage tank is used. Normally a cotton mill processing 100,000 pounds per day will discharge 10,000 pounds of BOD in 2.5 million gallons of wastes per day, and the design of the plant will have to be based on these loads, although it will receive no BOD or flow from the mill on Saturday and Sunday.

If enough BOD can be stored in the tank and discharged on Saturday and Sunday, the average BOD (50,000 pounds in 7 days) will be 7,143 pounds per day, a reduction of 29 percent. This may be done by discharging only 15,720 gallons of the concentrated desize waste per day and storing 14,280 gallons. On Friday night, 71,400 gallons would be left. Consequently, a 75,000-gallon tank should be used. Half of this volume (35,700 gallons with 7,140 pounds of BOD) may be discharged on Saturday; the other half on Sunday.

The BOD loading would be the same throughout the week, but on Monday through Friday, 3,140 pounds of BOD would be contributed by the desize process and 4,000 pounds by the other mill processes. On Saturday and Sunday, all of the BOD would be from the desize process.

The flow from the mill would be 2.5 mgd on Monday through Friday, but only 35,700 gpd on Saturday and Sunday. If necessary, some effluent may be pumped back to the head end of the plant to preserve hydraulic flows.

In some instances, the mill may wish to build its own activated-sludge treatment plant to treat the concentrated waste and discharge its effluent into the municipal sewer. With concentrated wastes, higher BOD loads of 200 lb/1,000 ft^3/day may be treated, and a much smaller plant may be used. For the 150,000 gallons and 30,000 pounds of BOD produced per week, a plant designed for 21,400 gallons and 4,285 pounds of BOD per day must be constructed. At a loading of 200 lb/1,000 ft^3/day, an aeration tank of 21,400 ft^3 (160,000 gallons) would also provide a detention time of 7.5 days. Such a plant should reduce the BOD by 90 percent; the remaining 10 percent (428.5 pounds) would be discharged to the municipal sewer. With this plan, the new mill effluent would be 2.5 mgd with 4,429 pounds of BOD on Monday through Friday and 21,400 gpd and 429 pounds of BOD on Saturday and Sunday. The design-BOD load has thus been reduced 56 percent and the aeration-tank volume and the aeration equipment of the municipal-treatment plant may be reduced accordingly. In addition, capital cost charges and operating charges will be reduced to provide a net savings.

Other means of disposing of the concentrated wastes should also be considered, as should the economics involved. Some of the possible methods are as follows:

- Incineration at municipal incinerator or company boiler

- Evaporation followed by incineration
- Reuse in processing
- Reuse as another product
- Treatment by chemical coagulation
- Treatment by chemical oxidation with chlorine, peroxide, permanganate, or ozone
- Treatment at high temperatures and pressures
- Treatment by ion exchange
- Treatment by reverse osmosis
- Anaerobic digestion

Some mills may be situated near regional incinerators that are large enough to handle the concentrated waste after it is sprayed evenly on the solid waste.

In order to reduce transportation costs, evaporation should always be considered to further reduce the volume. The 30,000 gallons of concentrated desize waste may be evaporated down to 7,500 gallons. Therefore, only one trailer tank truck will be needed instead of four to remove the waste from the mill.

Evaporation followed by incineration should also be considered, especially when the waste contains more than 6,000 mg/l BOD. Each 1,000 gallons contains 50 pounds of BOD.

Occasionally a concentrated waste may be reused within the mill for the same process or another process. All supervisors should be notified of the waste and its exact contents and asked to look into rinse possibilities.

Other industries may also be able to use the waste and all possibilities should be continuously reviewed. The high starch-sugar content of the desize waste makes its use for animal foods or alcohol fermentation highly likely. Wool grease may possibly be used for lanolin production or rust-prevention products. The waste and its analysis should be submitted to all likely users.

In some instances, chemical coagulation of the concentrated waste may provide adequate BOD reductions. It may not be used with the desize waste, since sugar is soluble and will not be precipitated. Wool grease and soap may be precipitated by calcium chloride, especially when treated to 140°-180° F, to produce BOD reductions of 70-90 percent.[4] The knitting and coning oils in the polyester-knit scour waste are present in colloidal emulsion, but these may be precipitated by the common coagulants. The disposal of the sludge from these treatments would be a problem.

Treatment by chemical oxidation or at high temperatures and pressures have been successful for some wastes.

Treatment of organic wastes by ion exchange is seldom done and would not be useful with these wastes. Reverse osmosis may be useful, but the brackish water left as a waste would be difficult to dispose of.

Anaerobic digestion could be used with these wastes if a large municipal digester is available. Normally, the digester may be loaded at 100 lb BOD/1,000 ft^3/day if properly stirred. For the desize waste above, a tank with 60,000 ft^3 (450,000 gallons) would be required, providing a detention time of 15 days. The waste would produce approximately 50,000 ft^3 /day of methane gas, which may be used to maintain the tank at 90° F for proper digestion. The moderate amounts of sludge produced could be disposed on agricultural lands or in landfills.

COD

It should be noted that COD, total oxygen demand, and TOC are rapid analytical measures of organic matter and are used in conjunction with the slower BOD determination. Consequently, the same procedures indicated above for BOD removal are used for COD removal.

In some instances, there may be adequate BOD removal but inadequate COD removal, indicating that soluble or colloidal nonbiodegradable organic matter is present in the waste. If further COD removal is required, all efforts to identify the nature of the compounds contributing the COD should be made, and biodegradable process chemicals should be substituted for the nonbiodegradable compounds. If this is not possible, treatment by chemical coagulation or activated carbon will have to be used, and costs will be doubled or tripled.

Chromium Removal

Chromium is usually used for oxidation in cotton and synthetic dyeing and for chemical fixation in wool dyeing. Usually, sodium dichromate, the hexavalent or oxidized form of chromium, is used, and a small percentage of chromic (trivalent) chromium is produced on reduction. The hexavalent form is yellow and soluble at all pH's, while the trivalent form is greenish and insoluble at pH's above 6.5.

In cotton and synthetic dyeing, other oxidants (peroxide, air, stream) may be used in place of the dichromate, and complete chromium removal may be obtained.

In wool dyeing, excessive chrome add-ons are often used. A considerable reduction in effluent chromium concentrations may be obtained by reducing the add-ons.

When removal is desired, the soluble hexavalent chromium must be reduced to the insoluble chromic chromium. This may be done with sodium metabisulfite at pH's below 4.0 or with copperas (ferrous sulfate) at any pH. When concentrations are below 50 mg/l, copperas is preferred. Treatment directly at the source is preferable, since the concentration in the effluent of most mills is very low, usually below 2.0 mg/l. The sludge may be removed by chemical flotation or by sedimentation in a tank providing 1-2 hours' detention. When copperas is used, a final pH of at least 8.5 is required, since the ferrous iron is soluble at pH's below that. With bisulfite reductions, a pH of 6.5-9.0 is satisfactory.

Phenolics

Phenolics indicate chemical compounds containing the phenol structure. Low concentrations in the parts-per-billion range may cause off-tastes in drinking water after chlorination or in fish. Many process chemicals, including some detergents, have this structure as part of the molecule, but the major source is probably the phenol used in the phenol-formaldehyde resin used for final finishing. The only discharge from the final finishing process is the excess solution left in the pad or impregnating trough. This should never be dumped to waste. It may be sprayed on the wastepaper or wood collected in the mill and incinerated.

Activated sludge will oxidize most of the phenolics if the associated chemical structure is not too complicated, but the rigorous treated-effluent guideline concentrations may still be exceeded. When this happens, a process-chemical survey may reveal the probable source, and treatment or process-chemical substitution should involve the point of origin. Chemical coagulation or oxidation with potassium permanganate may be useful in removing these compounds.

Sulfide

Sulfide usage in textile processing is very low, and sulfide is never present in most mill wastes. If present, the pH should be kept in the alkaline region of 9-10 to prevent the volatilization of the very odorous hydrogen sulfide. The activated-sludge process will readily oxidize sulfide to sulfate. Generally, the presence of sulfide will be no problem. The major source of trouble will be production of sulfide odors in the lateral lines to the sewage plant if acidic pH's are produced by other wastes in the system. If desired, sulfide may be oxidized by hydrogen peroxide, chlorine, hypochlorite, or potassium permanganate.

Oil, Grease, and Soap

Oil, grease, and soap are usually emulsified and readily treatable in the activated-sludge process. In some instances the emulsion may be broken, and scum and sticky deposits may form. Soap and vegetable oils are readily biodegradable, but the coning and knitting oils used for wool and polyester knits may on occasion be nonbiodegradable mineral oils. The latter may possibly reduce oxygen transfer in aeration and contribute high COD's in the final effluent.

If pretreatment is to be done, it probably should be done at the source. This will usually involve the wool scour and the first portion of the wash after fulling in woolen mills, and the first scour in polyester-knit mills.

The segregated concentrated wastes may be evaporated and incinerated or they may be treated by chemical coagulation with calcium chloride at 120°-140° F or with the common coagulants. Chemical flotation for sludge recovery may prove more satisfactory than sedimentation. The waste sludge should be incinerated.

It is believed that pretreatment for these substances will not be required unless floating oil or grease is obviously present in the waste.

Detergents (MBAS, ABS, LAS)

Detergents are usually measured by the methylene-blue test as methylene-blue active substances (MBAS) and may be composed of alkyl benzene sulfonates (ABS), normally considered as nonbiodegradable, and linear alkyl sulfonates (LAS), normally considered as biodegradable. The nondegradable ABS compounds are no longer manufactured for general detergent use, but they may be used in some textile operations in which a considerable portion may pass through the activated-sludge treatment process. When reductions are required, the most practical way is to trace the source (e.g., through a process-chemical inventory survey) and eliminate its use by substituting a biodegradable LAS detergent or even soap.

Chemical coagulation with the common coagulants may be useful, but costly, and should be tried if necessary. When possible, only the major source of the detergent may have to be treated to provide adequate reductions.

Color

If required, color removal will probably be the greatest problem in textile-waste treatment, since it can be attained only at great cost in most instances. Unfortunately, determination of color in textile wastes is a complicated analytical process, and information on color is seldom included in textile-waste surveys.

A fairly simple test to estimate the approximate color content of a waste is to determine the dilution with tap water (or stream water) necessary to reduce the color to extinction. If a dilution of 50 times were necessary, the sample was considered to have a dilution to extinction (DTE) of 50X. If there were 20,000 gallons of the waste, the total color units produced by the waste would be considered to be 20,000 × 50, or 1 million color units. In this manner, the relative number of color units from the various sources could be estimated, and the major sources of color could be identified. In one commission house, the fugitive colors in the desize waste (25,000 gal/day) produced a DTE of 600X and a total color of 15 million color units. The mill also dropped 100,000 gallons of exhausted concentrated dye baths with a DTE of 150X and a total color of 15 million units. The major source of color, however, was caused by the batch dumping of the waste print pastes from the color shop. These pastes had a very high color content with DTE's of 30,000X-600,000X (average 80,000X). The mill dumped 400 gallons per day, producing 32 million color units. The print pastes thus contributed 52 percent of the total color, and the dye baths and the desize waste each produced 24 percent each. Subsequent investigations have indicated that many printing mills waste as much as 1,000-2,000 gallons of print pastes per day, and color contribution by the batch-dumped pastes may amount to 60-80 percent of the total color. It is obvious that the waste-print pastes should never be dumped into the effluent. Segregation and separate disposal of only 400-2,000 gallons per day will produce an immediate color reduction of 50-80 percent. In the mill, the pastes are sprayed on the solid wastes at the local incinerator.

When color removal is required, all means of reducing the color in the waste must be used. This may involve the following:

- Segregate all waste-print pastes, if any, and dispose separately in landfill, ocean, or incinerator.
- Reduce losses in the color shop by careful hand cleaning of all brushes, troughs, doctor blades, cans, tanks, and screens.
- Attempt to get weaving mills to reduce the use of fugitive tints in weaving.
- Try to exhaust the dyes more thoroughly in the dye process.
- Use dye processes that cause less color loss, for example, solvent, pad-and-steam, microfoam, methanol, and ammonia dyeing.

Following this, only the concentrated color wastes should be segregated and treated, as this may possibly produce enough color removal to satisfy the requirements. This will usually involve the exhausted-dye baths and the color-shop wastes (cleanup, wash after printing, and blanket wash). These may be treated with chlorine, hydrogen, peroxide, potassium permanganate, sodium bisulfite, or chemical coagulation with the common coagulants (ferric, ferrous, and aluminum sulfates or chlorides and/or lime).

If adequate removals are not obtained, the treated effluent may be further treated by passage through a granular activated-carbon filter. Usually, however, prior passage through a sand or mixed-media filter is necessary to prevent clogging of the carbon.

If the uncollected rinses contain too much color, the entire mill effluent will have to be treated.

Phosphate

In some instances, phosphate removal may be required. If so, it may be more readily done by substituting nonphosphate chemicals such as ethylene-diaminetetraacetic acid and others for the phosphates normally used. If treatment is necessary, phosphate may be readily reduced to below 1 mg/l by chemical coagulation with ferric, ferrous, and aluminum salts or with lime.[5] The coagulation may be done before, after, or even in the aeration tank of the activated-sludge process.

Nitrogen

Nitrogen in wastes may occur as ammonia, nitrite, nitrate, or organic nitrogen. In biological oxidation, ammonia may be converted to organic nitrogen in the bacterial bodies and to nitrites and nitrates. The organic nitrogen may be removed as sludge, but the unconverted ammonia, nitrite, and nitrate are soluble and will be present in the effluent. In some cases, oxidation of the ammonia in the stream may deplete the oxygen resources in the stream, since ammonia has a very high potential oxygen demand of 423 percent.[6] In addition, ammonia has a very high chlorine demand and may raise chlorine use for disinfection to high levels. This may also tend to make the effluent toxic to fish because of the chlorinated amines produced.[7]

Ammonia removal may be accomplished in two ways. Carbonaceous BOD such as methanol may be added to the aeration tank to convert the excess ammonia to organic nitrogen as bacterial bodies and removed as sludge.[8] It also may be removed by raising the pH to 9-11 with lime or sodium hydroxide and aerating the mixture to gasify the ammonia.[9]

Nitrites and nitrates cause problems since they may be denitrified by certain bacteria to produce nitrogen gas, which causes sludge rising in secondary settling basins. In addition, they may cause excessive algae growths in the receiving stream. They may be removed by creating favorable conditions for the denitrification process, described above, to occur.[9]

The best way to solve the nitrogen problem is to limit ammonia, nitrite, and nitrate use in processing. If such use is fixed to produce a BOD:N ratio of 100:5, practically all of the nitrogen will be converted to organic nitrogen and removed as sludge.

REFERENCES

[1] *Regulation of Sewer Use*, Manual of Practice No. 3, Washington, D.C., Water Pollution Control Federation, 1968.

[2] J. W. Masselli, N. W. Masselli, and M. G. Burford, "Factors Affecting Textile Waste Treatability," *Textile Industries, 135*, 84, 1971.

[3] T. W. Brandon and S. Grindley, "Effect of Nitrates on the Rising of Sludge in Sedimentation Tanks," *Sewage Works Journal, 17*, 652, 1945.

[4] J. A. McCarthy, "A Study on Treatment of Wool Scouring Liquors," *Sanitalk, 3*, 17, May 1955.

[5] U.S. Environmental Protection Agency, "Process Design Manual for Phosphorus Removal," Washington, D.C., EPA Technology Transfer, Oct. 1971.

[6] J. W. Masselli, N. W. Masselli, and M. G. Burford, "BOD? COD? TOD? TCC?" *Textile Industries, 136*, 53, 1972.

[7] Anonymous, *Chemical and Engineering News*, Apr. 23, 1973, p. 36.

[8] "Cleaning Our Environment. The Chemical Basis for Action," American Chemical Society Report, p. 133, Washington D. C., 1969.

[9] Carl E. Adams, Jr., "Removing Nitrogen from Waste Water," *Environmental Science and Technology*, 7, 696, 1973.

Chapter VIII
SUMMARY

THE WASTE SURVEY, MAJOR SOURCES OF WASTE, AND FLOW REDUCTION*

In summarizing and discussing the water-pollution subjects, the two main topics are current technology and treatment-plant operation, as well as those future technological advancements or changes to operation. This summary deals with those current practices in the technology of wastewater treatment: the waste survey, major sources of waste, and flow reduction.

The Waste Survey

The waste survey provides a characterization of wastewater, both from the effluent waste stream and the individual contributing waste sources in the textile plant. The preliminary wastewater survey gives a general overview of the wastewater problem, as well as basic design criteria for wastewater-treatment programs. The whole integrated plan for the wastewater survey generates preliminary information for the design of wastewater-treatment-plant construction and provides the necessary insight into the wastewater-treatment process so that manufacturing process changes can be adequately anticipated as they affect the effluent quality.

The preliminary waste survey deals with obtaining knowledge concerning the volume of wastewater required and fluctuations in daily requirements. It is concerned with a determination of the wastewater characteristics in terms of concentration or strength and the major in-plant wastewater sources—their reduction and control. The survey also deals with the environmental impact as the treated waste effluent is discharged to the receiving stream.

The tools of the wastewater survey are the water/wastewater "budget," the manufacturing operation, and a raw-materials survey. The water/wastewater budget is concerned with sources of wastewater and collection of the effluent. Simultaneously with determination of the water-balance quantities, sampling of the effluent sources are made. Both individual waste-source sampling and analysis are performed, as are total effluent sampling and monitoring of discharge volume.

As a part of the waste survey, manufacturing operations and raw materials are to be included. A materials balance can be developed for each line of the textile operation. These include the fabric or textile products, the dyeing or finishing product, and the wastewater from each production unit. The analytical work associated with the waste survey indicates that a substantial amount of laboratory analysis may be required. Depending on the quantity of effluent discharged, consideration should be given to operating a wastewater-analysis laboratory at the textile plant. The cost can often readily be justified by consideration of the cost of equivalent analytical work by outside, independent laboratories.

The detailed waste survey follows the preliminary survey as a smooth transition from the basic knowledge to the detailed data collected. The detailed survey can begin to be concluded after approximately 1 year's collection of data. It serves to firmly establish design criteria and provide better waste characterization. In a 1-year period, the detailed survey will show seasonal variations, as well as production irregularities. The detailed survey should be a refinement of the preliminary

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procedures, that is to say, more precision in the water/wastewater balance. As with the preliminary survey, the detailed survey should reflect waste parameters expressed in terms of pounds of production.

The continuing monitoring phase of the survey serves as the firm basis for rational design of wastewater-treatment systems. This continuing monitoring phase is the standard for operational purposes and for purposes of comparing alternatives. Those alternates addressed here are variations in production and in chemicals used in the textile process. When the continuing monitoring survey permits in-plant monitoring, the results can be expressed in terms of each department, whose cost expressed per pound of production includes pollutional load, flow, and overall treatment cost.

Major Sources of Waste

In a discussion of major sources of waste from textile operations, a classification or categorization of the textile industry has been presented and described in eight general categories. In any effort to describe the wastewater from the textile industry, only generalizations should be emphasized. The major wastewater characteristics have been given as a range of compositions that might occur, and it has been impressed that pinpoint interpretations lead to errors in characterization of the waste. Classical studies have indicated that textile production sources should be categorized based on the predominant fiber of the three major categories: wool processing, cotton processing, and synthetics processing. A description of both the BOD and the effluent quantity have been given for each of these groups.

A further breakdown of the sources of wastewater gives a description of the pollutional characteristics of the various processes. Included in the processes are the pollutional loading of dye carriers, the breakdown of wool wet processes into individual operations, and a similar breakdown for cotton and synthetic fibers. Discussions have been given of the effect of sizing different from starch and the resultant reduction in BOD. However, looking beyond this one characterization indicated a possible greater effluent concentration of COD. Variation in products that cause variations in the effluent serve as one example of the need for consistent and continuous monitoring of the textile-wastewater effluent. The variability apparent in the effluent is controlled substantially by compositing practices in wastewater monitoring. Proper compositing produces effluent concentrations similar to that of the actual waste stream. Without the benefit of composite waste samples, any sample concentration may be considerably different from the actual waste stream.

Flow Reduction

Water savings is not a matter of pure academic importance but is a current practical necessity. This need for effluent flow reduction is caused by higher costs and by the greater demand of Federal and State agencies for wastewater-pollution control. This results in a greater incentive for the textile plants to reduce their quantity of water flow.

Implementing a program of water conservation has been described and encompasses six general actions:

- Stop the supply of water when production equipment is stopped.
- Reduce the quantity of water used to the minimum amount.
- Modulate the water supply depending on the speed of the textile products handled.
- Reuse nonchemical-treated cooling water by use of cooling towers for recycle.

- Reuse chemical-treated water, since some textile processes do not require the high quality of water that other units require.

- Utilize steam condensate return and reuse. Examples or case histories have been presented showing 75-percent and 45 percent water conservation.

WATER REUSE, WASTE SEGREGATION, AND SUBSTITUTION OF PROCESSES AND MATERIALS*

Before getting into the more sophisticated areas of control and regulation of waste output, it is necessary that all the primary steps, discussed previously in chapter III, be taken. While on this subject, it should be noted that before attempts are made to reduce flow, the actual magnitude of the flow should be known with accuracy. In other words, the watermeter or meters into the plant should be completely reliable. This may seem to be a very obvious point, but many plants seem to have very little idea of their actual water consumption due to inadequate or faulty watermeters. It is also necessary that there be a knowledge of where the water use in the plant is taking place in relation to particular areas, such as dyeing versus finishing, and whenever possible, in relation to individual machines or ranges. This means that either flow meters or watermeters should be installed in lines to machines or particular areas where this is feasible. Once a very accurate fix has been obtained on exactly where the major areas of water use are, then work can be concentrated on these areas toward a reduction in water use. Too much time is spent in trying to reduce water consumption on machines and ranges that use quite small amounts of water. Efforts should be concentrated where effort will be repaid. There is also the question of maximum water-use efficiency. Different wash-box designs, of course, give different degrees of liquid interchange between bath and fabric. Anything that can improve the balance and improve the efficiency of interchange will enable the plant to cut back on the water usage on a particular operation.

Water Reuse

Much talk is heard today about the possibility of reusing water, and several operations are reusing at least some of their various types of water that would otherwise be directed straight into the effluent-treatment system. The simplest example of water reuse, and one that has been used for quite a long time, is the counterflowing of wash boxes on a range. In a counterflow situation, water is actually reused to a number of times equal to the number of boxes counterflowed. The water from the last box, instead of being dumped, is reused in the previous box, and so on. This is by far the most economical way of running a series of wash boxes, and it has no disadvantage in washing efficiency over a range in which boxes are individually dumped. Thus, there seems to be no reason, extending this principle, why water from "clean" processes cannot be reused in more "dirty" processes. For example, water from bleach range wash boxes should be quite suitable for making up desizing, scouring, or mercerizing liquors. Unfortunately, however, this type of reasoning presupposes a fairly wide range of activities being pursued in one particular mill, and this is not always the case. It also assumes either that output and product mix is fairly consistent, or that an extremely flexible piping system can be installed.

After considering the reuse of process water in other processes, consideration should also be given to the nonprocess water and its reuse, either in actual fabric contact processes or reuse again as nonprocess water. Such water is, for example, condenser cooling water, water from water-cooled bearings, heat-exchanger water, and the like. Here it can be postulated that not only water reus and savings will arise from this, but also the recycling of heat energy. Thus, heated cooling water could be stored and reused in a dyehouse as process water already partially heated, reducing dyehouse heating costs. One of the large water users in a yarn dyehouse is the water that is run through the enclosed package drier condenser system to cool the air after it has passed through the yarn packages, thus removing the moisture that it contains before reheating and recirculating. There is quite a massive output of this water from a single unit. A typical figure might be 1½ million gallons per week. This could be recycled as process water.

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Waste Segregation

Waste segregation is a rather complicated subject. Many people have talked about the apparent foolishness of running more-or-less clear rinse waters together with concentrated pad bath liquors into the same treatment facilities. The argument is why dilute a concentrated effluent and make it more difficult to treat? But, what *does* one do with slightly contaminated water? It is not feasible to set up an entirely different waste-treatment facility for cleaner water. Here, perhaps, there is a tie-in with the previous subject of water reuse. Water should not be discharged to the waste facility until it is absolutely nonreusable for any purpose because of the amount of contaminant it contains. Thus, dirty wastewater would be sent to the lagoons and more-or-less clean water to the dirtier processes. This objective may not be within the reach of all of us, but the idea of holding wastes of certain characteristics until such time as those characteristics are needed in the lagoons is interesting and, given a sufficient amount of piping and a sufficient amount of tanks, would seem to be quite feasible.

Substitution of Processes and Materials

One area that seems to hold out a great deal of hope for improvements in the waste situation is that of substitution of processes and materials. Lists of a variety of textile chemicals with their BOD values have been assembled. If there is a choice of two chemicals to use, the one with the lower BOD is preferable. Similar reasoning applies to toxicity. However, in this area of substitution of materials, it is not likely that a substitute will be found for the prime material: water. There has been much recent talk about solvent processes, and 5 years ago it seemed that a whole new textile technology was opening up. This early promise has not been fulfilled, except for special processes, such as knit scouring and some finishing. There may be a future for solvents in desizing, with the idea of recovery of solvent, soluble sizes, and reuse, although one would imagine that this would probably mean a radical change in the greige mill so that the greige mill setup would provide solvent desizing facilities at the mill and then reuse of the recovered size. As far as bleaching and dyeing are concerned, it seems that solvent processing at present offers little promise. The only dyes that readily dissolve in solvents that are suitable are disperse dyes. This, of course, limits us to synthetic fibers and also even eliminates some of the better classes of dyes for these fibers. Other dyes, such as water-soluble dyes for natural fibers, need to be dissolved in mixed solvents or emulsions or complicated systems of this kind. This leads to a multitude of problems in bath stability and solvent recovery as well as to problems relating to the constancy of composition of the mixed bath. Another factor is that at present, dyes are sold either with deliberately added or accidentally added diluents, most of which are insoluble in the solvents considered for possible use in textile operations.

Thus, at least purer dyes need to be produced. Not many years ago, dye manufacturers were promising ranges of solvent-soluble dyes, which would be applicable readily to most classes of fibers. These ranges, needless to say, have not yet materialized. In order to be practical on a large scale, it is necessary to advance to the stage where only one solvent for desizing, scouring, bleaching, dyeing, and finishing is required. It would obviously be impractical in a complex plant to have three or four different solvents being used for different operations, each with a recovery unit.

Thus far, the engineering problems relating to solvent processing have not been considered. The figure often quoted as being necessary for economic feasibility is 98 percent recovery, and many machinery manufacturers indicate that this level is possible with their equipment. However, in the plant, the story seems to be a great deal different. Even at the 98-percent recovery level, vast amounts of solvent will escape into the air from a large mill operation and lead to extremely severe air-pollution problems, not particularly from the solvents themselves, perhaps, but from the products subsequently produced by actinic degradation. There are also the problems of within-plant toxicity, and the Occupational Safety and Health Act (OSHA) here has restrictive regulations. Even in a simple operation such as dry cleaning of knits with solvents, problems have arisen due to spillage, inadequate engineering of recovery units, leaks in machinery, and the sucking of fumes from the solvent units into the combustion zones of gas-fired tenters with resultant production of acidic fumes and damage of fabric. Therefore, it seems that water will continue as the prime medium for 95 percent of the textile operations for many years to come, and that the greatest area for improvements lies in that of chemical substitution, for example, peroxides and other per compounds being used in oxidation processes instead of metal-containing salts, such as chromates, and polyvinyl alcohol instead of starch, along with low-foaming detergents.

PRETREATMENT OF TEXTILE WASTES*

If it can be shown that elimination of any substance that may have even the slightest ecological significance can be economically achieved, pretreatment or elimination of its use may be ordered. At the present time, very few mills have to pretreat their wastes to protect the treatment system or process, although each mill will have to inspect its discharge thoroughly to make certain of this fact. If pretreatment is necessary, it probably will involve screening for lint, fiber removal, or, less likely, pH regulation of highly alkaline wastes from cotton mills using the mercerization process without caustic recovery.

Many sewage-treatment-plant operators are fearful of accepting textile wastes for combined treatment and may ask for excessive and often unnecessary pretreatment. They should be shown the results from any of the many plants that are successfully treating these wastes without pH adjustment or equalization throughout the country. In the next few years, the number of textile-waste-treatment plants will increase many times, and a considerable amount of new data will be available.

Many of the problems that may possibly be produced by textile wastes can be eliminated through in-plant process or process-chemical substitution. This type of effluent modification should be reviewed continuously. One of the greatest needs at the present time is an accurate analysis of the process chemicals being used by the industry, since these chemicals produce 99 percent of the solids in all textile effluents (except wool-scouring wastes). Each process chemical should have the BOD, TOC, theoretical oxygen demand (ThOD), biodegradability, phenolic content, ABS content, total solids, and metallic content on its label. In addition, the pollution potential of each process suggested by the process-chemical manufacturer should be indicated in pounds of BOD and ThOD per 1,000 pounds of cloth. The plant supervisor may then use the processes that will cause less pollution and less pretreatment.

Weaving, knitting, and thread mills should provide exact information on the amount and type of slashing sizes, lubricants, etc., on each product, and the BOD and ThOD loads that they will produce when desized or scoured.

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*Prepared by Joseph W. Masselli, Nicholas W. Masselli, and M. G. Burford of the Industrial Wastes Laboratory, Wesleyan University, Middletown, Conn.

The industry must thoroughly review the reason for use of each chemical and its impact on pretreatment, treatment, ecology, and end disposal.

Methods involving the least color loss in printing and dyeing will be most important, since color is readily noticeable and will be the cause of most future complaints by the public, in spite of the fact that color has a minimal pollutional effect and is soon dissipated.

The use of soluble inorganic compounds that are difficult to remove (sodium chloride, hydroxide, sulfate, bicarbonate, carbonate, etc.) should be reduced as much as possible. They may be replaced by recoverable or disposable inorganics, such as ammonia or phosphate, or possibly by biodegradable organic compounds. If reduced to low enough concentrations, the possibility of recycling the activated-sludge effluent for reuse in the mill may be greatly enhanced.

Whenever possible, discharge of concentrated wastes (above 6,000 mg/l BOD) into water should be avoided. Segregation and separate disposal by reuse, new-product formation, evaporation and incineration, anaerobic digestion, and other means should be investigated.

Waste-print pastes especially should never be dumped into water, since they not only contain a considerable amount of BOD but they are the major color sources also.

Hydrocarbon solvent usage should be reduced to an absolute minimum, since they have very high BOD's and only one or two barrels per day may contribute as much as 1,000-2,000 pounds of BOD. In one mill, elimination of hydrocarbon use in print-paste makeup reduced the effluent BOD load from 6,000 pounds to 2,000 pounds per day—a fantastic reduction through the elimination of only one process chemical.

The simplified chemical inventory survey can be of great value in keeping track of loads and in tracing trouble sources. It should be reviewed continuously in conjunction with production charts. Each mill should know the approximate water use, BOD, and total solid and alkalinity loads expected from the kind of processing they do and should make certain they are within the usual limits. If not, they probably are using excessive add-ons or high-BOD chemicals.

It is highly probable that in-plant changes involving process or process-chemical substitution will be used in place of pretreatment or treatment and will provide less expensive and more satisfactory remedies when offending substances or qualities are present in the waste.

The only certainty about pretreatment is that the degree and nature of it will be changed several times in the future when new and more specific information becomes available. Such information will be increased tremendously in the next year or two, since all textile wastes will now be treated and the required analytical results will become available for review. Research projects on the compiling of such information should start immediately.

The determination of the nature, the amount, and the source of the residuals in all effluents is of great importance and should be the object of future study. There is no doubt that industry and society can do a much better job of protecting its stream resources than it has in the past.

Part II

AIR-POLLUTION ABATEMENT

Chapter I

THE EMISSIONS SURVEY*

One rarely embarks on an emissions survey without at least some notion of what to look for. The usual question is not, What? but How much? Ignoring the well-known problems arising from steam raising and waste incineration, the next most prevalent air pollutants that come from the textile industry are hydrocarbons. Finishing operations are especially culpable.

Thanks to certain pressures from the guardians of receiving waters, and to pronounced thermal economies as well, there is a trend toward the use of hydrocarbon solvents for such steps as scouring, dyeing, coating, and the application of fire retardants, for example. (Pioneer issues of the *Reviews of Progress in Coloration* may be consulted for examples.) Many of these solvents are, because of their low photochemical reactivity, exempt from regulation as air pollutants. Trichloroethylene is an exception in some jurisdictions.

A more severe problem arises from chemical reactions employed in resin finishing and bonding. Reactions are sometimes an inadvertent, or at least inessential, result of high-speed thermal treatments, such as flame laminating. There is always the urge to raise the temperature in order to process more goods, whereupon simple softening turns toward scorching. What makes these problems severe is the often unknown nature of the reaction products and the difficulty of predicting or even controlling their rates of production. Compounding this difficulty is the special pollutant category in which such products are placed. The language of the law refers typically to "baked, heat-cured, or heat-polymerized" goods and, in the tradition of the celebrated Rule 66 of the Los Angeles County Air Pollution Control District, the emissions to the air of byproducts from goods so processed are limited to 15 pounds per day.

An intermediate case creates a special problem. Polyester knits are heat set or "tentered," for reasons of fiber mechanics, but often as well to drive off the heavy organic carriers used in disperse dyeing. Conditions are severe enough that low-molecular-weight fractions of the polymer are evaporated; these, with or without dye carriers, are then emitted to the atmosphere where they condense into an oily fog, the "blue haze." Such an emission is mechanically an aerosol; it is subject to regulation as a visible emission, as a particulate. But chemically, it is a hydrocarbon, and some of the carriers are on the list of hazardous materials recognized by OSHA. Perhaps, it can be argued that the source of these emissions is not "heat-curing" in the spirit of Rule 66.

These, then, are the principal sources in the textile industry, again excepting steam raising and waste incineration.

It may not be clear why all hydrocarbons—even some that cannot be smelled and have no direct consequences to human health—should come under regulation. And how does it happen that the several States, responding to uniform guidelines for the preparation of implementation plans,[1] should emerge with so variable a group of regulations?

A close reading of the guidelines reveals that regulations affecting the emission of hydrocarbons are almost exclusively concerned with their contribution to the problem of photochemical oxidants, which *are* a direct menace to human health. The problem is occasionally so bad in Los Angeles that school children are forbidden to go outside and play at recess time. It follows that

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*Prepared by David B. Marsland of the North Carolina State University at Raleigh.

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the several States, if latitude is granted them under the law, will view the hydrocarbons problem as severe in direct relation to their oxidants problem. Further, hydrocarbons are logically categorized in terms of their reactivity under ultraviolet illumination in the atmosphere, as established by careful (but not always unambiguous) research. According to these findings, methane is not a contributor; many regulations accordingly deal in "nonmethane hydrocarbons." Moreover, since the products of incomplete combustion are chemically quite similar to intermediates in the photochemical reactions leading to oxidants, it is understandable why special attention is paid to flame processing and heat curing. Finally, since exhaust from the internal combustion engine has long been recognized as a major contributor of hydrocarbons, the technology of sampling and analyzing hydrocarbons owes its advanced state to the automobile. We look, in fact, to Federal regulations[2] on the testing of prototype automobiles for guidance.

Precisely because these emissions are ordinarily present in the air at high dilution (less than 1 ppm), there has emerged a marvelously sensitive analytical method: the hydrogen flame ionization detector (FID). Because a large volume of air is required in this method, it has been found useful to collect the sample in a large plastic bag. Because hydrocarbons are soluble in such plastics as polyethylene and Saran, the preferred bags are made of polyvinyl fluoride, an expensive material. To insure that certain of the heavier hydrocarbons do not condense when the gas sample is cooled to ambient conditions, metered quantities of dilution air may be required. (Even dilution air is inadequate to prevent the condensation of portions of a tenter-frame exhaust.) Because methane is not in this category, these components would, if present, have to be separated and corrected for. In summary, take a large sample in a special plastic bag, with metered dilution air if need be, measure TOC by FID, and correct for methane and CO.

As indicated above, tenter-frame exhaust will severely tax the survey team. It is probably best sampled as particulate matter, using a filter or, better, an impinger, which demonstrably collects it. In a sense, we are really fortunate that the particle size of this aerosol is nearly uniform—a consequence of the mode of its formation. The collection device is likely to be either a success or a miserable failure. A high-volume sampler, which might be used to study the ambient atmosphere, will probably inhale too much dilution air when misused as a stack sampler; it will be entirely unsuitable for determining the efficiency of a control device. A conventional sampling train should be used for particulate matter by insertion into the ductwork before the exhaust can cool appreciably. It will be necessary to wash these with a volatile solvent, so that the oil can be determined by evaporating it. (*Caution:* Ether and chloroform are favorites for this step.) It might seem sufficient to use a simpler bubbler, but this exhaust will at this point be a fine aerosol, not a gas, and the collection efficiency of most bubblers is inadequate.

Mill management would almost certainly employ a consulting engineer to perform the kind of sampling and analysis described above, were it not for the obligation of periodic reporting to some of the States. A reading of the current air-pollution regulations of the several States in Region IV suggests that mills in North Carolina, Kentucky, and Tennessee should take note.

REFERENCES

[1] "Code of Federal Regulations," chapter 40, part 51, as found in the *Federal Register:* 36 FR 22398 of Nov. 25, 1971; 36 FR 24002 of Dec. 17, 1971; 36 FR 25233 of Dec. 30, 1971; 37 FR 26310 of Dec. 9, 1972; and 38 FR 6279 of Mar. 8, 1973.

[2] "Code of Federal Regulations," chapter 40, part 85, as found in the *Federal Register:* 36 FR 22448 of Nov. 25, 1972; 37 FR 669 of Jan. 15, 1972; 37 FR 18262 of Sept. 8, 1972.

Chapter II

PARTICULATE CONTROL*

SOURCE, EFFECT, AND ANALYSIS OF THE PARTICULATE EMISSIONS

Polyester and other synthetic cloth may be heated before or after dyeing or printing in dryers or tenter frames, with air temperatures in the 300°-400° F range, in order to prepare it for a subsequent process or to give it certain finished characteristics. At these temperatures, a portion of any residual spinning and knitting oils, resins, or other high-boiling-point organics in the cloth will be volatilized and eventually exhausted to the outside air. Before being emitted, or as it mixes with outside air, the oils or other organics cool enough to condense as an odorous, bluish-white, submicron smoke.

Depending on the amount of residual organics in the cloth, this smoke can be in violation of the visible emission regulation (Ringelmann 1 or 20 percent opacity) by a wide margin, if uncontrolled. Based on limited information, it appears that as far as residual oils are concerned, a violation is likely to occur when the cloth contains 0.5 percent or more by weight. Due to the visible and odorous nature of this emission, many justifiable complaints to the air-pollution-control agency from people within 1,000 feet or so of the stack have also resulted in citations for violation of nuisance or odor regulations. Depending on stack height, local topography, and meteorological conditions, this distance can change significantly. This smoke by weight is a relatively small emission and, thus, will not be in violation of a particulate-emission (by weight) regulation, which all States now have. However, if the State has a hydrocarbon-emission regulation, the smoke plus any organics still in the gaseous state in the exhausted air could result in a violation, because this type of regulation is more weight restrictive.

Before methods of abatement are explored, a determination of the types, state, and amounts of constituents in the emissions should be made. The quickest and cheapest way is a chemical analysis of the organics in the cloth, both before and after the high-temperature heating process. This analysis possibly could be done by a company chemist. The results and a prediction of the effect on the organics by the heating and subsequent cooling can provide good information about the emission constituents. The most accurate and complete information is provided by source sampling done in the exhaust ductwork or stack from the dryer or tenter frame. However, this requires special equipment and a team of at least two people trained in its use. Source sampling is, therefore, usually a hired service and costs on the order of $1,000-$5,000, depending on the number of stacks sampled and the extent of the analysis of the samples taken.

EXPECTED EFFECTIVENESS AND RELATIVE COST OF VARIOUS METHODS OF ABATEMENT

Before considering an emission-control system, the possibility of a process change, which would reduce the amount of residual organics in the cloth, should be explored. The easiest and cheapest change would be an additional or more effective scouring at some stage of processing prior to high-temperature heating. The results of better scouring are limited in many cases, but could at least reduce the required effectiveness of a control system. Dry cleaning can remove the residual organics so well that unless another high-boiling-point organic is used in a subsequent process, no emission control is needed on the exhaust of an eventual heating process. Unfortunately, a continuous dry-cleaning system is expensive and has been installed primarily for productive effects rather than pollution control. However, a mill with a visible-emissions violation should consider it as a possible alternative to an entirely nonproductive exhaust-control system.

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*Prepared by Thomas M. Noel of the Rhode Island Department of Health, Providence, R.I.

There are three basic approaches to exhaust-emission control that have representative equipment installed in dyeing and finishing mills: incineration, scrubbing, and electrostatic precipitation. For any control system, a working estimate is that the installation cost will equal the cost of the control device alone. Incineration is highly effective on any organic emission. Complete oxidation is obtained if the incinerator is operated at 1,300°-1,500° F, with a residence time of approximately 0.5 second. The only possible drawback to the effectiveness of incineration occurs if a substantial amount of a chlorinated hydrocarbon is present as hydrochloric acid is a byproduct. Chlorinated hydrocarbons are sometimes used as dye carriers, but it is not known whether the residual from the dyeing process is enough to be a problem. The main disadvantage of incineration is a high operating cost—\$2/h/1,000 ft^3/min. The addition of a heat-recovery system can cut this cost in half, but will double the equipment cost and increase the maintenance cost.

Scrubbers collect the smoke most efficiently if they are a high-energy type, that is, with a large pressure drop between inlet and outlet. Since the residual oils are only slightly soluble in water, absorption is not the important collection mechanism. After sufficient cooling to condense the volatilized oils, impaction between the smoke particles and the scrubbing liquid is potentially the primary one. For submicron particles, the latter mechanism can be efficient only if there is a large energy input. For runs of cloth with relatively large amounts of residual oils, it appears that the scrubber must have a 40-inch (H_2O) pressure drop to comply with the 20-percent opacity limit. Although some low-energy scrubbers (less than 10-inch pressure drop) significantly reduce the smoke, none will provide compliance under this circumstance. An important disadvantage of the high-energy scrubber is its relatively high operating cost due to the power requirement. Equipment costs do not seem to vary much with scrubber type—\$2.50/ft^3/min is a typical price.

Electrostatic precipitators (ESP) can sufficiently collect submicron smoke to comply with the opacity limit, if they are operating properly. In this application, the temperature prior to entry into the ESP must be low enough to condense the volatilized oil to smoke. Any low-boiling-point organics remaining in the gaseous state in the exhaust will not be collected, and any associated odor could still be a problem. Fortunately, in many cases, these are not present in significant amounts, and the disagreeable odor is mostly associated with the oil smoke. To operate properly, the collection surfaces of the ESP must be kept reasonably clean. For this reason, a prescrubber for solid particulates, which would otherwise cake on the surfaces, or a system for automatic cleaning must be added in some applications. The operating cost of an ESP is relatively low, mainly because of the small amount of electrical energy required (100 W/1,000 ft^3/min). The equipment cost may be somewhat less than a scrubber.

CASE HISTORIES OF RECENTLY INSTALLED CONTROL EQUIPMENT

High-Energy Scrubber

The installation is on a 5,000 ft^3/min exhaust of a tenter frame in Coventry, R.I. It is a venturi-type scrubber utilizing surfactant and alkaline additives and is operated at a 34-inch H_2O pressure drop. Several similar models of this scrubber have been installed at mills in North Carolina. The one in Rhode Island was installed in the spring of last year after several years of complaints by many neighborhood residents to the mill, the town council, and the State air-pollution-control agency. During the period of complaints, there was an ineffective spray scrubber on the tenter-frame exhaust. There are a considerable number of homes within a 100-1,000 feet range from the stack.

Since the installation, there have been no complaints of smoke or odor to the mill or the air-pollution-control agency. However, for the first several months after installation, there were complaints of noise due to the 100-horsepower fan on the scrubber, which is located on the roof of the mill. The scrubber and the motor-fan combination were enclosed in a soundproofed housing at the time of installation, but it was not until the exhaust stack was also enclosed that the noise was reduced enough to bring an end to the complaints. Although there has been, in general, a large reduction in visible emissions (and odor), opacity limits are not always met. The violation (approximately 50 percent opacity) occurs on runs of cloth known to contain the largest amount of residual oils (1 percent by weight according to the plant manager). They constitute approximately 10 percent of the production through the tenter frame. This scrubber-fan system is capable of being operated at 42 inches H_2O. Significant reduction of the smoke from these runs would be expected if it were so operated.

Low-Energy Scrubber

The installation is on a 10,000 ft^3/min exhaust of a tenter frame in Pawtucket, R.I. It is a packed-bed, cross-flow, two-stage scrubber, utilizing surfactant and alkaline additives. It is operated at a 3-inch H_2O pressure drop. Several similar models of this scrubber have been installed on tenter frames in New Jersey. It was installed this past summer, again, after many complaints from neighborhood residents, the nearest of whom is approximately 300 feet from the stack.

Since the installation, there have still been complaints of smoke and odor. Certain runs of cloth produce smoke with approximately 50 percent opacity. Although it has not as yet been determined, it is likely that these runs contain relatively larger amounts of residual oils than the runs that do not cause a violation. Although this scrubber has reduced the smoke and odor considerably from the uncontrolled situation, it is unlikely that it can be operated with a significant increase in efficiency. If this proves to be the case, one solution would be to reduce the residual oils by scouring or dry cleaning.

Chapter III

SOLVENT PROCESSING AND RECOVERY*

During the past several years, we have seen many and varied changes taking place in the processing of textile products. One of the most dramatic of these has been the increase in popularity of knitted fabrics. Because of the different requirements in the treatment of the supply yarns for the knitting machine, as opposed to those of the loom (such as oil-base lubricants rather than cornstarch, CMC, or PVA sizes), several new processing steps in the field of dyeing and finishing are being added to those traditionally used to cope with the changing demands.

In the processing of piece-dyed fabrics, oil-base lubricants are applied on the texturizing machine or winder. The lubricant is normally emulsified and washed from the fabric by an aqueous scouring procedure at the beginning of the dye cycle. This practice deals with relatively small amounts of solvents in low concentrations and makes solvent recovery impractical at present.

The processing of fancy or yarn-dyed goods makes the use of solvent-processing equipment supported by solvent-recovery systems much more attractive and productive. Here, the lubricant is applied to the yarn during the winding operation following yarn dyeing. After knitting, the lubricant must be removed from the fabric to allow the successful application of various finishes to provide the desired fabric characteristics. At this point, the manufacturer must choose between the more conventional aqueous method of emulsifying the lubricant, followed by washing and rinsing, or solvent removal through the utilization of either batch or continuous dry-cleaning machines. Many considerations, not the least of which is the growing concern for the elimination of water pollution and the ever-tightening regulations in this area, encourage the selection of nonaqueous systems, or those that will minimize water requirements and thereby reduce and simplify the problems of plant-effluent treatment. The use of solvent versus aqueous systems has demonstrated reduction in total plant-water requirements of 20 gallons per pound to 5 gallons per pound. It must be pointed out that this comparison is based on the performance of different plants rather than actual reduction in one plant.

Upon making the decision to employ solvent processing in a manufacturing plant, provisions must also be made for solvent recovery to make the process economical and to provide air-pollution protection. Solvent-processing equipment and solvent-recovery systems are so intimately related that the most reasonable approach for the purchase of both systems is to buy an integrated system for solvent processing and recovery from a single supplier. This gives the plant the distinct advantage of single responsibility for the successful installation and ensuing operation of the equipment.

Upon beginning the installation of solvent-processing and recovery equipment in a manufacturing plant, the plant manager and his staff are faced with somewhat new and different problems, and many familiar problems have taken on greater importance.

The solvent-processing and recovery equipment must, as nearly as possible, totally contain the solvent used (normally perchlorethylene) to assure a safe atmosphere for employees and to provide for maximum solvent recovery to make the process economical. OSHA regulations place limitations on the amount of perchlorethylene in the plant atmosphere. This requirement states that the concentration of perchlorethylene may not exceed 100 ppm on an 8-hour, time-weighted average, and shall not exceed 300 ppm for more than 5 minutes during any 3 hours of an 8-hour period. Perchlorethylene detectors are considered essential to provide data necessary to assure compliance with the regulations and serve as a guide for the plant maintenance staff in detecting leaks and malfunctions of the solvent-handling and recovery equipment. Perchlorethylene detection devices are available in both permanently mounted and portable models. Additionally, the fixed units have indicating and recording features, as well as the capability to sound alarms, actuate warning lights, etc. Detectors should be mounted at the entry and exit ends of processing machinery, in the area housing the solvent-recovery equipment, and at any other point that may be susceptible to solvent leaks. At least one portable unit is recommended to allow monitoring in areas not covered by fixed units and to assist in detecting and locating solvent leaks.

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*Prepared by Raymond M. Allen of Deering Milliken Service Corporation, Spartanburg, S.C.

It has been theorized that excessive perchlorethylene concentrations in the plant atmosphere may cause additional problems. Assuming that the burners on gas-fired tenters draw in solvent fumes with the combustion air, convert the fumes to hydrochloric acid gas, and deposit this on the fabric, it is conceivable that at some point, solvent concentrations in the plant air could cause browning of the cotton compound of cotton-polyester blends and degradation of dyes resulting in off-shade goods. It has not been determined exactly what the critical concentration of perchlorethylene may be, but it is generally expected to be in the 200-500 ppm range.

Actual problems experienced by a plant in the installation, startup, and operation of a solvent dry-cleaning process with solvent recovery are summarized as follows:

- Solvent consumption: Solvent consumption during the startup phase of the equipment can be expected to run as high as 20-30 percent. After debugging and fine tuning the equipment, consumption can be expected to decrease to 5-8 percent. Attaining the manufacturer's claims of 3 percent solvent consumption appears difficult, if not impossible, to attain.

- Solvent leaks: contributing factors

  - Machinery vibrations
  - Poorly or improperly fitted couplings and flexible hoses and kinks in hoses
  - Failure of door seals on machines
  - Malfunctions of recovery units

- Squeeze-rool deterioration

Chapter IV
SUMMARY*

The presentations on air pollution have pointed out the complexity of an air-pollution-control and abatement problem, but have also shown that practical measures are available to reduce substantially the volume and concentration of emission streams. The material discussed has included the survey, whose purpose is to identify the nature and extent of an emission problem, a review of the sources of emission problems and discussion of available measures for their control, and, finally, a discussion of solvent-processing technology, by which some of the inherent problems of air and water pollution in textile finishing may be avoided.

SURVEY AND ANALYSIS OF EMISSION PROBLEMS

To identify and evaluate the nature of a plant's emission problem generally requires fairly sophisticated instrumentation and testing methods, beyond the normal capability of plant personnel. While a general idea of the emission components can be obtained by having samples of the textile product analyzed before and after each emission-generating operation, a detailed stack analysis, which can be performed by a number of professional service organizations, will define the nature of the emission and provide data for selection of proper control devices.

SOURCES

The sources of air-emission problems are relatively few and can be characterized in a number of ways: unit operations, fiber content, materials used, etc.

In terms of unit operations, texturizing, atmospheric dyeing and finishing, and drying and curing processes constitute the major sources of emissions, with drying and curing undoubtedly the largest single source. In terms of fiber content, the greatest problem is associated with polyesters, primarily due to the volatile carriers required in the disperse dyeing process and the oil-based processing lubricants that must be applied for efficient handling and fabric formation. Both the carriers and the lubricants, which are added to the material for proper processing, must be removed later in finishing. Smoke is produced when textiles coated with lubricating oils or plasticizer are heated to 300°-400° F in tenter frames, dryers, curers, and ovens. At these temperatures, oils and waxes in the fiber volatilize and evaporate. Upon cooling to the dew point, condensation takes place, forming an aerosol of submicron oil droplets that appear as the blue-gray smoke. These particles range from 0.01 to 1 micron (human hair diameter is 100 microns). These particle sizes scatter light perfectly, and even a small concentration can produce a highly visible smoke. Typical particulate codes require stack emissions to be less than 0.02 grain/ft^3 (from a 5,000 ft^3/min exhaust, 1 pint of oil per hour exceeds the requirement). It is possible to have as little as ½ of 1 percent oil content on the fabric and still exceed air-pollution-code requirements. In addition to being highly visible, the smoke is also usually odorous.

Other sources include formaldehyde or other resin-finish-related material evolved in the application and curing of functional finishes, volatilized spin finish as filament yarns are heated during texturizing, and partial degradation and combustion products from flame-bonded laminating or singeing processes. Because of factors such as high temperature or humidity and safety considerations, most sources are usually enclosed or vented, and emission control can be readily applied to the exhaust stream.

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*Prepared by G. G. Tewkesbury of the Institute of Textile Technology, Charlottesville, Va.

ABATEMENT AND CONTROL MEASURES

Measures to reduce emissions can involve both process changes and emission control. A number of possible process changes were discussed. Additional scouring and rinsing steps may be used to remove lubricants and carriers more completely before a fabric is subjected to elevated temperatures, but the benefit of doing so must be weighed against the additional wastewater-treatment problem generated. Replacement of older atmospheric wet-finishing equipment, with enclosed or pressurized equipment, should be considered.

Substitution of solvent processing for aqueous processing is a possibility, although presently limited in scope, particularly in dyeing. Solvent scouring of knit polyester seems to have commercial application, although fully economic operation will depend on attaining higher levels of solvent recovery. Examples of such solvent-scouring systems are shown schematically in figures IV-1 and IV-2. An important feature of any solvent system is containment and recovery of solvent evaporated from the fabric. Without effective recovery, substantial volumes of solvent would be exhausted to the atmosphere. It is estimated that if the 950 million pounds of knit polyester and nylon finished last year had been solvent scoured, with a recovery rate of 99 percent, nearly 10 million pounds of solvent would have been injected into the atmosphere. At present, experience indicates that 95 percent recovery is a more realistic value. More research and development efforts are needed to make solvent processing more widely applicable. Present systems for collection and recovery of solvent vapors are based on adsorption and desorption of solvent in activated-carbon beds. A schematic of this mechanism is shown in figure IV-3.

In addition to process changes, emission controls can be applied to the exhaust streams. An obvious first step to reduce control costs, however, would be to determine if existing exhaust rates are necessary. Reduction in total cubic feet per minute should lower the specifications and costs of any control equipment.

Practical, available technology for treatment of textile air streams seems to center on scrubbers, which collect particles and dissolve some gaseous products in a water spray; electrostatic precipitators, which ionize particles and collect them on charged plates; and incineration units, which oxidize organics at temperatures up to 500° F. While commercial units of all types are available, initial costs, effectiveness, operating and maintenance costs, and energy requirements vary widely and must be carefully weighed against the particular stack-emission problem.

It now appears that the textile industry's air-pollution problems, in general, are more amenable to solution than those of other industries, primarily because the sources of emission are limited to relatively few processes that can be isolated. When they do occur, however, they generally present a substantial problem, such as in the dyeing and drying of polyester pile carpets.

In the context of the truism that everything must go somewhere, caution must be observed in undertaking an air- or water-pollution-control program—solution of one problem does not simply convert an emission problem into an effluent problem, or the reverse. For example, solution of a particulate-emission problem by application of a scrubber system to the exhaust stream in turn creates a potential suspended-solids problem to be handled in processing the wet effluent. Likewise, use of extra scouring and rinsing steps to remove potentially volatile materials may reduce generation of fumes at the dryer or tenter frame, but will increase the volume of effluent to be treated. Substitution of a process-chemical material may alleviate a wash-treatment problem, but may create an

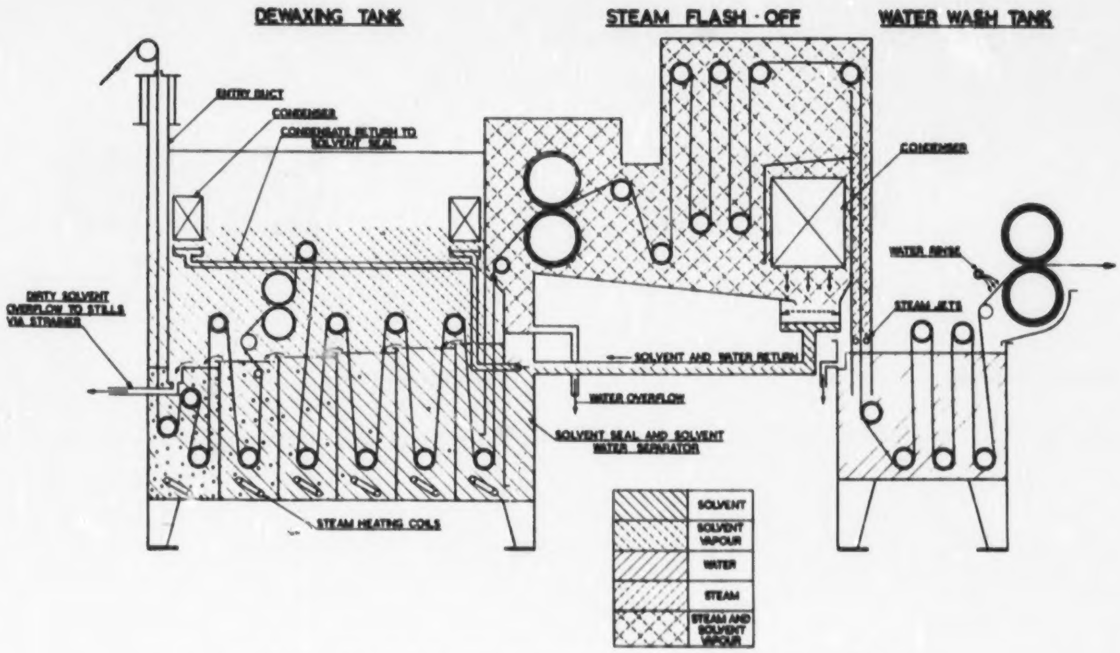
DEWAXING TANK
STEAM FLASH · OFF
WATER WASH TANK
ENTRY DUCT
CONDENSER
CONDENSATE RETURN TO SOLVENT SEAL
DIRTY SOLVENT OVERFLOW TO STILLS VIA STRAINER
CONDENSER
WATER RINSE
STEAM JETS
SOLVENT AND WATER RETURN
WATER OVERFLOW
SOLVENT SEAL AND SOLVENT WATER SEPARATOR
STEAM HEATING COILS
SOLVENT
SOLVENT VAPOUR
WATER
STEAM
STEAM AND SOLVENT VAPOUR

Figure IV-1. Typical machine arrangement for solvent scouring of fabrics.

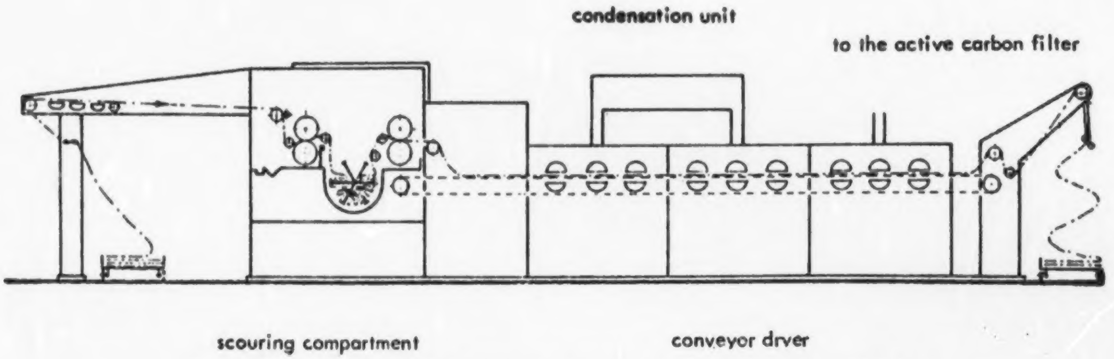
condensation unit
to the active carbon filter
scouring compartment
conveyor dryer

Figure IV-2. Fabric-travel diagram of a solvent-scouring range for knit fabrics.

entirely new air-pollution problem when the same chemical is subjected to interaction with other process chemicals and elevated temperatures in drying and curing.

As with water pollution, the cost of meeting air-quality standards becomes part of the cost of doing business. It is a task, however, that cannot necessarily be done by the least expensive measure or piece of equipment. As our ecology reflects the delicate balance and interaction among many dynamic biological systems, an efficiently operated, environmentally responsive organization reflects a critical balance and interaction among many dynamic physical, chemical, and economic systems. Application of effective abatement programs cannot be done by purchase of hardware alone, but requires careful deliberation and planning to insure that the necessary balance of all factors—product quality, economics, environmental effects, etc.—be maintained.

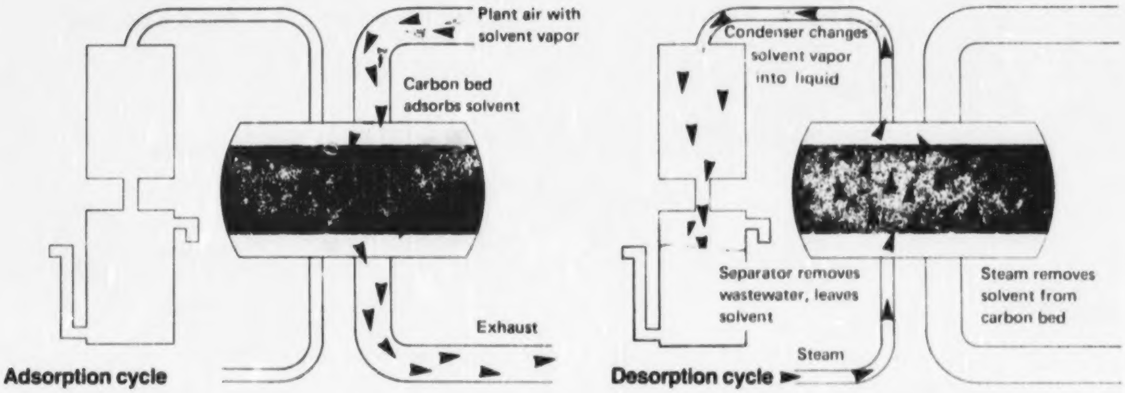
Plant air with solvent vapor
Carbon bed adsorbs solvent
Exhaust
Adsorption cycle
Condenser changes solvent vapor into liquid
Separator removes wastewater, leaves solvent
Steam
Steam removes solvent from carbon bed
Desorption cycle

Figure IV-3. Diagrammatic sketch of collection and recovery of solvent vapors using an activated-carbon bed.

Appendix A

TABLES OF ADDITIONAL DATA AND INFORMATION CHARACTERIZING TEXTILE PROCESS WASTES AND CONSTITUENTS

Table A-1.—*Pollution effects of cotton-processing wastes*

Item	Wastes, ppm		
	pH	BOD	Total solids
Slashing, sizing yarn	7.0-9.5	620-2,500	8,500-22,600
Desizing		1,700-5,200	16,000-32,000
Kiering	10-13	680-2,900	7,600-17,400
Scouring		50-110	
Bleaching (range)	8.5-9.6	90-1,700	2,300-14,400
Mercerizing	5.5-9.5	45-65	600-1,900
Dyeing:			
Aniline black		40-55	600-1,200
Basic	6.0-7.5	100-200	500-800
Developed colors	5-10	75-200	2,900-8,200
Direct	6.5-7.6	220-600	2,200-14,000
Naphthol	5-10	15-675	4,500-10,700
Sulfur	8-10	11-1,800	4,200-14,100
Vats	5-10	125-1,500	1,700-7,400

Table A-2.—*Pollution loads of wool wet processes*

Process	pH	BOD, ppm	Total solids, ppm
Scouring	9.0-10.4	30,000-40,000	1,129-64,448
Dyeing	4.8-8.0	380-2,200	3,855-8,315
Washing	7.3-10.3	4,000-11,455	4,830-19,267
Neutralization	1.0-9.0	28	1,241-4,830
Bleaching	6.0	390	908

Source: J. J. Porter et al., "Water Uses and Wastes in the Textile Industry," *Environ. Sci. Tech., 6*(1): 36-41, 1972.

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Table A-3.–*Pollution load of synthetic wet fiber processes*

Process	Fiber	pH	BOD, ppm	Total solids, ppm
Scour	Nylon	10.4	1,360	1,882
	Acrylic/modacrylic	9.7	2,190	1,974
	Polyester		500-800	
Scour and dye	Rayon	8.5	2,832	3,334
	Acetate	9.3	2,000	1,778
Dye	Nylon	8.4	368	641
	Acrylic/modacrylic	1.5-3.7	175-2,000	833-1,968
	Polyester		480-27,000	
Salt bath	Rayon	6.8	58	4,890
Final scour	Acrylic/modacrylic	7.1	668	1,191
	Polyester		650	

Source: J. J. Porter, "Water Uses and Wastes in the Textile Industry," *Environ. Sci. Tech., 6*(1): 36-41, 1972.

Table A-4.–*Simplified survey–cotton mills, 1958*

[78,000 gallons and 96 pounds BOD per 1,000 pounds of cloth]

Item	Solids, mg/l	BOD, mg/l	Percent of total BOD
Grey goods contribution:			
Starch (desize)	176	104	70
Natural impurities (kier)	81	31	21
Subtotal	257	135	91
Process chemicals with BOD:			
Soap	3.3	4.6	3.1
Acetic acid	13.1	4.2	2.8
Sodium hydrosulfite	27.2	1.5	1.0
Urea	20.5	1.8	1.2
Rhozyme LA	10.9	0.2	0.1
Tergitol NPX	15.1	0.3	0.2
Detergent MPX	2.8	<0.1	<0.1
Subtotal	91.9	12.6	9
Process chemicals without BOD:			
Caustic soda (100 percent)	514	0	0
Sodium bicarbonate	63	0	0
Sodium hypochlorite	57	0	0
Sodium chloride	35	0	0
Sulfuric acid	32	0	0
Sodium silicate	16	0	0
Sodium carbonate	14	0	0
Phosphoric acid	11	0	0
Hydrogen peroxide (30 percent)	7	0	0
Sodium chlorite	6	0	0
Subtotal	755	0	0
Grand total	1,104	148	100

Source: J. W. Massilli, N. W. Massilli, and M. G. Burford, "Factors Affecting Textile Waste Treatability," *Textile Indust.*, 135: 84, 1971.

Table A-5.—*Simplified survey--cotton-synthetic mill, 1969*

[25,000 gallons and 47 pounds BOD per 1,000 pounds cloth]

Item	Solids, mg/l	BOD, mg/l	Percent of total BOD
Grey goods contribution:			
Synthetic sizing	40	20	9
Starch (desize)	200	140	62
Natural impurities (kier)	neg.	0	–
Subtotal	240	160	71
Process chemicals with BOD:			
Acetic acid	26	14	6
LAS detergent	7	11	5
Print paste solvent	100	24	11
EDTA	29	8	3
Sodium hydrosulfite	38	8	3
Rhozyme	88	2	1
ABS detergent	7	< 1	
Subtotal	288	67	29
Process chemicals without BOD:			
Sodium chloride	752	0	0
Hydrogen peroxide (30 percent)	68	0	0
Sodium hydroxide	25	0	0
Hydrochloric acid	24	0	0
Sodium carbonate	21	0	0
Zinc sulfate	20	0	0
Sodium tripoly phosphate	18	0	0
Sodium silicate	12	0	0
Magnesium chloride	8	0	0
Sodium sulfate	5	0	0
Sodium nitrite	5	0	0
Potassium permanganate	2	0	0
Subtotal	960	0	0
Grand total	1,488	227	100

Source: J. W. Masselli, N. W. Masselli, and M. G. Burford, "Factors Affecting Textile Waste Treatability," *Textile Indust.*, 135: 84, 1971.

Table A-6.–*Simplified survey–viscose rayon velvet mill, 1968*

[30,000 gallons and 38 pounds BOD per 1,000 pounds velvet]

Item	Solids, mg/l	BOD, mg/l	Percent of total BOD
Grey goods contribution:			
Antistat lubricant	16	12	8
Gelatin size	60	40	27
Subtotal	76	52	35
Process chemicals with BOD:			
Detergent	53	46	31
Lubricant–penetrant	34	12	8
Resin finish (waste)	150	28	19
Acetic acid	19	12	8
Subtotal	256	98	65
Process chemicals without BOD:			
Sodium chloride	588	0	0
Sodium sulfate	108	0	0
Sodium phosphate	36	0	0
Sodium hydrosulfite	24	0	0
Hydrogen peroxide (35 percent)	12	0	0
Subtotal	768	0	0
Grand total	1,100	150	100

Source: J. W. Masselli, N. W. Masselli, and M. G. Burford, "Factors Affecting Textile Waste Treatability," *Textile Indust.*, 135: 64, 1971.

Table A-7.–*Simplified survey–woolen mill, 1953*

[60,000 gallons and 425 pounds BOD per 1,000 pounds finished wool]

Item	Solids, mg/l	BOD, mg/l	Percent of total BOD
Grease wool contribution:			
Grease, suint, dirt	3,000	500	61
Subtotal	3,000	500	61
Process chemicals with BOD:			
Soap	152	236	28
Acetic acid	24	15	2
Pine oil	10	11	1
Carding oil	10	2	1
Spinning oil	8	1	<1
Detergents	90	60	<1
Subtotal	294	325	39
Chemicals without BOD:			
Soda ash	340	0	0
Sodium phosphate	10	0	0
Sulfuric acid	4	0	0
Chrome mordant	20	0	0
Sodium sulfate	8	0	0
Subtotal	382	0	0
Grand total	3,676	825	100

Source: J. W. Masselli, N. W. Masselli, and M. G. Burford, "Factors Affecting Textile Waste Treatability," *Textile Indust.*, 135: 84, 1971.

Table A-8.—*Wool-scouring and wool-finishing wastes*

<table>
<tr><th colspan="2">Wool-scouring wastes (250 pounds BOD per 1,000 pounds cloth)</th></tr>
<tr><th>Item</th><th>Approximate analysis[1]</th></tr>
<tr><td>Chemical add-ons:</td><td></td></tr>
<tr><td>20-25 percent grease</td><td>pH 10-12</td></tr>
<tr><td>7-10 percent suint</td><td>15,000 mg/l BOD</td></tr>
<tr><td>50 percent sand</td><td>36,000 mg/l TS[2]</td></tr>
<tr><td>1 percent Na_2CO_3</td><td>12,000 mg/l sand</td></tr>
<tr><td colspan="2">Wool-finishing wastes (200 pounds BOD per 1,000 pounds cloth)</td></tr>
<tr><td>Wash after fulling:</td><td></td></tr>
<tr><td>2-8 percent carding oil</td><td>pH 10-12</td></tr>
<tr><td>5-10 percent soap</td><td>9,000 mg/l BOD</td></tr>
<tr><td>1 percent Na_2CO_3</td><td>18,000 mg/l TS</td></tr>
<tr><td>0.5 percent penetrant</td><td></td></tr>
<tr><td>Wash after carbonizing:</td><td></td></tr>
<tr><td>5-6 percent H_2SO_4</td><td>pH 4.0</td></tr>
<tr><td>1-2 percent Na_2CO_3</td><td>100 mg/l BOD</td></tr>
<tr><td>Aluminum chloride</td><td>4,000 mg/l TS</td></tr>
<tr><td></td><td>3,000 mg/l sulfate</td></tr>
<tr><td>Stock dyeing:</td><td></td></tr>
<tr><td>5 percent acetic acid</td><td>pH 7.0</td></tr>
<tr><td>3 percent chromate</td><td>3,000 mg/l BOD</td></tr>
<tr><td>2 percent penetrant</td><td>3,000 mg/l sodium acetate</td></tr>
<tr><td>2 percent fatty acid leveler</td><td>7,000 mg/l TS</td></tr>
<tr><td></td><td>50-250 mg/l chromium</td></tr>
<tr><td>Alternate:</td><td></td></tr>
<tr><td>10 percent NH_4 sulfate</td><td>pH 7.0</td></tr>
<tr><td></td><td>450 mg/l BOD</td></tr>
<tr><td></td><td>6,000 mg/l NH_4 sulfate</td></tr>
<tr><td colspan="2">Combined finishing waste</td></tr>
<tr><td></td><td>pH 10-11</td></tr>
<tr><td></td><td>4,000 mg/l BOD</td></tr>
<tr><td></td><td>9,700 mg/l TS</td></tr>
<tr><td></td><td>1,000 mg/l sulfate</td></tr>
<tr><td></td><td>15-90 mg/l chromium</td></tr>
</table>

[1] It is assumed that 2,000 gallons of water is used for each 1,000 pounds of cloth in each process.

[2] TS indicates total solids.

Note.—Masselli suggested (May 1973 AATCC Symposium, Washington, D.C.) that tables A-8, A-9, A-10, and A-11 be inspected also to obtain an idea of the nature of various wastes.

Table A-9.–*Cotton finishing*

[100-200 pounds BOD per 1,000 pounds cloth]

Item	Approximate analysis[1]
Chemical add-ons: Desize 10 percent starch 0.5 percent enzyne	pH 6.8 3,000 mg/l BOD 6,000 mg/l TS[2] 4,300 mg/l carbohydrates
Alternate: 5 percent PVA	pH 7.0 300 mg/l BOD 7,000 mg/l TS 6,000 mg/l PVA
Caustic scour: 4-8 NaOH 1 percent waxes, pectins 0.5 penetrant	pH 13.0 1,800 mg/l BOD 8,000 mg/l TS 3,600 mg/l NaOH
Combined desize/scour	pH 10-13 4,800 mg/l BOD 14,000 mg/l TS 3,600 mg/l NaOH 4,300 mg/l carbohydrates
Bleaching: 2 percent H_2O_2 2 percent Na silicate 0.3 percent NaOH	pH 9-11 600 mg/l BOD 1,200 mg/l H_2O_2 1,000 mg/l Na silicate 240 mg/l NaOH
Mercerizing: 2-6 percent NaOH	pH 11-14 780 mg/l BOD 8,000-18,000 mg/l TS 3,000-6,000 mg/l NaOH
Dyeing: 2-4 percent dyes 1-3 percent leveling 1-3 percent emulsifying 1-3 percent softening 0.5 percent chelating 0.5-30 percent NaCl	pH 4.5-8.0 200-30,000 mg/l BOD 500-40,000 mg/l TS 100-30,000 mg/l NaCl 400-1,000 X dilution to reduce color
Printing-waste pastes	pH 4.0-8.0 50,000-400,000 mg/l BOD 500,000 mg/l solvent 500,000 mg/l TS 30,000-600,000 X dilution to reduce color
Printing-wash after printing 1 percent detergent PVA adhesive	pH 4.5-8.0 600-1,800 mg/l BOD 1,200-3,600 mg/l TS
Combined equalized effluent	pH 11-13 1,200-2,400 mg/l BOD 4,000-12,000 mg/l TS 500-1,500 mg/l NaOH 1,000-4,000 mg/l NaCl 500-3,000 mg/l TOC 1,500-4,500 mg/l COD

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[1] It is assumed that 2,000 gallons of water is used for each 1,000 pounds of cloth in each process.

[2] TS indicates total solids.

Table A-10.—*Polyester knits*

[30-60 pounds BOD per 1,000 pounds cloth]

Item	Approximate analysis[1]
Chemical add-ons:	
Scouring waste:	
3-10 percent coning-knitting oils	pH 7.0
0.5 percent detergent	1,200 mg/l BOD
	4,000 mg/l TS[2]
	3,000 mg/l oils
Dye waste:	
2-3 percent acetic acid	pH 3.8-4.6
3-6 percent perchloroethylene	1,000 mg/l BOD
1 percent naphthalene sulfonic acid	1,000 mg/l acidity
4 percent lubricant	2,200 mg/l perchloroethylene
1 percent defoamer	1,000 mg/l acetate
0.5 percent EDTA	
Alternate carriers:	
3 percent trichlorobenzene	
3-4 percent butylbenzoate	
4-10 percent biphenyl	
Combined equalized effluent	pH 4.5-5.2
	1,100 mg/l BOD
	3,100 mg/l TS
	1,500 mg/l oils
	900 mg/l perchlorethylene
	500 mg/l acetate

Table A-11.—*Other synthetics—rayon, acetate, nylon, Dacron, Orlon*

[40-100 pounds BOD per 1,000 pounds cloth]

Item	Approximate analysis[1]
Chemical add-ons	pH 7.0 300-1,800 mg/l BOD 2,000-10,000 mg/l TS[2]

[1] It is assumed that 2,000 gallons of water is used for each 1,000 pounds of cloth in each process.

[2] TS indicates total solids.

Table A-12.–*Field analysis of rug-dyeing and associated wastes*

Process	Color	Odor	Turbidity (mg/l as silica)	pH[1]	Conductivity at 25°C, µratios /cm	Estimated TDS, mg/l	Floatable solids, percent	Settleable solids, percent
Tap water	Clear, colorless	None	<10	8.10 at 74° F 7.70	630	409.5	0	0
Rug beck, chemical added with no color dye	Cloudy, murky gray, with yellowish tint	Slight	180[2] 500	8.85 at 80° F 8.70	6,400	4,160.0	0	0
Rug beck liquor, begin of dye cycle	Deep green	None	>840	9.10 at 83° F 8.80	7,375	4,793.8	0	0
Rug beck liquor, near middle of dye cycle	Deep olive green	None	>840	8.85 at 115° F 8.60	9,000	5,850.0	0	0
Rug beck liquor, end of dye cycle	Brown green	Slight "medical" odor	>840	8.20 at 115° F 8.10	8,750	5,687.5	0	0
Rug beck rinse	Clear, colorless	None	33	6.60 at 78° F 7.15	700	455.0	0	<0.1
Boiler make-up	Clear, colorless	None	14.0	8.50 at 110° F 7.65	635	412.8	Trace	0
Boiler blowdown	Murky, light gray, white floatables	None	400	11.25 at 126° F 11.50	8,250	5,362.5	Trace	<0.1
Zeolite backwash	Clear, colorless	None	12.3	8.60 at 72° F 8.60	930	604.5	0	0
Basin effluent	Murky, yellow colloidal matter	None	600	8.40 at 85° F 8.10	1,210	786.5	0	<0.1
Clarifier effluent	Fairly clear, with brown solids	Slightly musty	300	8.25 at 80° F 7.65	925	601.3	Trace	<0.1
Basin effluent[3]	Varies with color of dye	Varies from none to slight	174	7.14 at 70° F	1,748	1,136.0	Trace to none	0.24

[1] First recorded pH value was determined within 1 hour of sampling. Second recorded value determined on 2-17-66 when all samples were at 68° F.

[2] First recorded turbidity value taken on 2-16-66. Second value taken on 2-17-66. Large difference indicates some chemical reaction occurred.

[3] Average characteristics of six samples taken from 9:30 a.m. to 4:30 p.m. on 3-24-66.

Source: Ralph Stone, "Carpet Mill Industrial Waste System," *J. Water Poll. Con. Fed.*, 44(3): 474, 1972.

Appendix B

TABLES ILLUSTRATING RELATIVE AMOUNTS USED AND BOD LOADINGS OF CHEMICALS CONSUMED IN COTTON FINISHING AND COMPARISON OF VIEWS ON ACCEPTABLE CRITERIA FOR TEXTILE PROCESS WATER

Table B-1.–*Cotton-finishing process chemicals, consumption and BOD*

Chemical	Amount used, lb/1,000 lb goods	BOD, percent[1]	BOD, lb/1,000 lb goods
B-2 gum	22	61	13.4
Wheat starch	16	55	8.8
Pearl cornstarch	14	50	7.0
Brytex gum No. 745	4	61	2.4
KD gum	4	57	2.3
Slashing starch	[2]96	–	53.0
Total	150	–	82.9
Carboxymethyl cellulose	–	3	–
Hydroxyethyl cellulose	–	3	–
Tallow soap	20-100	[3]55	11-55
Nacconal NR	1	4	0.04
Ultrawet 35 KX	–	0	0
Acetic acid, 80 percent	27	52	14.0
Mixture of 18 dyes	37	7	2.6
Cream softener, 25 percent	20	39	7.8
Formaldehyde-bisulfite condensate	14	27	3.8
Glycerin	3	64	1.9
Sodium hydrosulfite	11	22	2.4
Urea	13	9	1.2
Finish total solids	8	39	3.1
Kierpine extra	5	61	3.1
Merpol B	4	44	1.8
Glucose	–	71	–
Gelatin	–	91	–
Caustic, 76 percent	118	(4)	(4)
Soda ash	42	(4)	(4)
Ammonia	7	(4)	(4)
Potassium carbonate	3	(4)	(4)
Trisodium phosphate	2	(4)	(4)
Sodium perborate	3	(4)	(4)
Sodium silicate	6	(4)	(4)
Liquid soda bleach	4	(4)	(4)
Hydrogen peroxide	5	(4)	(4)
Sodium chloride	7	(4)	(4)
Sodium dichromate	6	(4)	(4)
Sulfuric acid	10	(4)	(4)
Hydrochloric acid	6	(4)	(4)

[1] Based on weight of chemical; for example, 1 pound of B-2 gum (61 percent BOD) would require 0.61 pound of oxygen for stabilization.

[2] Calculated from analytical survey.

[3] Apparently contained high water content; dry soaps averaged 130 to 150 percent BOD.

[4] Negligible BOD assumed.

Source: J. W. Masselli, N. W. Masselli, and M. G. Burford, "A Simplification of Textile Waste Survey and Treatment," New England Interstate Water Pollution Control Commission, Boston, Mass., 1959.

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Table B-2.—*Analysis of a sample of acceptable process water*

Particulars of the impurities	Quantity of the impurity present, ppm	
Total dissolved solids	TDS	200.00
Suspended matter	turbidity	1.50
Total alkali	$CaCO_3$	100.00
Total hardness	$CaCO_3$	15.00
Ferrous salts	Fe_2O_3	0.05
Manganese salts	MnO_2	0.05
Silica	SiO_2	10.00
Aluminum salts	Al_2O_3	0.40
Other heavy metals	R_2O_3	0.10
Color (platinum units)		5.00
pH		7.5-8.0

Source: *Colourage*, Apr. 20, 1972.

Table B-3.—*Upper permissible limits for dyeing source: Three different sources*

Item	1	2	3
Color, ppm	2-5	5-20	5
Total hardness as $CaCO_3$, ppm	10-25	15-30	10-30
Alkali to MeO as $CaCO_3$, ppm	35-65	150	75-100
Fe, ppm	0.03-0.10	Nil	0.01-0.02
Mn, ppm	0.02-0.10	0.05	0.01
Total dissolved solids, ppm	65-150	100-200	200
Suspended solids, ppm	Nil	5	Nil
pH	7.0-7.5	6.5-7.5	7.0
Chloride, ppm	0-30	Low as possible	20-40
Sulfate, ppm	0-30	80-100	–
Silica as SiO_2, ppm	Nil	0.5-120	–
Aluminum, ppm	Nil	0-0.25	0.30-0.40

Source: *Textile J. Australia*, Nov. 1970.

Table B-4.—*Average "limits" of concentration of impurities for many textile-processing operations*

Item	ppm
Turbidity, ppm as silica	0.5-3
Color, ppm platinum scale	2-5
Total hardness, ppm as $CaCO_3$	0-25
Iron, ppm as Fe	0.02-0.1
Manganese, ppm as Mn	0.02
Alkalinity to methyl orange, ppm as $CaCO_3$	35-64
Total dissolved solids	65-150

Source: *Tex. Chems. and Aux.*, V. J. Calise (Graver).

Table B-5.—*Tolerable limits of various substances in the textile industries*

Item	Cotton, silk, and man-made fibers, mg/l	Wool, mg/l
Total hardness	70	100
SO_4	250	250
Cl[1]	250	250
NO_3	0.5	0.5
PO_4	([2])	([2])
TDS	500	500
Free Cl_2	0.1	0.1
Fe	0.3	0
Mn	0.05	0
Cu[3]	0.01	0
Al	0.25	0.25

[1] SO_4 and Cl must not vary; this is more important than absolute value.

[2] No limit within reason.

[3] Any heavy metals as Cu.

Source: *J. Soc. Dyers Colorists*, 481, Dec. 1971.

Table B-6.—*General textile-processing water-quality specifications*

Item	Cotton	Rayon
Turbidity, mg/l as SiO_2	0-25	1.0
Color	0-50	5.0
Hardness, mg/l as $CaCO_3$	0-50	10.0
Iron, mg/l as Fe	0-0.2	0.05
Manganese, mg/l as Mn	0-0.1	0.02
Total dissolved solids, mg/l	200	200.0
Aluminum, mg/l as Al		0.25
Heavy metals, mg/l	0.01	0.01
Silica, mg/l as SiO_2	10	10.0
Alkalinity, mg/l as $CaCO_3$	75-100	75.0

Source: T. A. Alspaugh, Proceedings 13th SMIWC, 1964.

Table B-7.—*Analysis of fresh water typically used by finishing plants*

Item	Plant A	Plant B	Plant C
BOD_5	0	0	0
COD	5	2	6
Total solids	50	92	60
Dissolved solids	45	88	58
Suspended solids	2	4	2
Volatile solids	9	20	5
pH	7.5	7.6	7.8
Alkalinity	18	36	10
Hardness	3	8	12
Phosphorus	0.1	–	–
Total nitrogen	0.6	–	–
Nitrate	0.3	–	–
Chloride	–	0.6	–

Note.—All results are reported in ppm except pH and were performed according to "Standard Methods for the Examination of Water and Wastewater" (13th Edition).

Source: J. J. Porter, *Am. Digest Rep., 79,* Apr. 1973.

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	µm.		3.937 X 10^{-3}=10^{3}A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or	t	1 tonne = 1 000 kg	0.984 ton (long) =
	megagram	Mg	1 Mg = 1 000 kg	1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N-m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity				
linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2.120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa-s		0.00672 poundals/sq ft
Pressure	newton per square metre	N/m^2		0.000145 lb/sq in
	or pascal	Pa		
	kilometre per square metre	kN/m^2		0.145 lb/sq in.
	or kilopascal	kPa		
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	degree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/t		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes				
diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	$lumen/m^2$		0.092 ft candle/sq ft